Mitigating Threatened Species Bycatch in Commercial Gillnet Fisheries

Project Report

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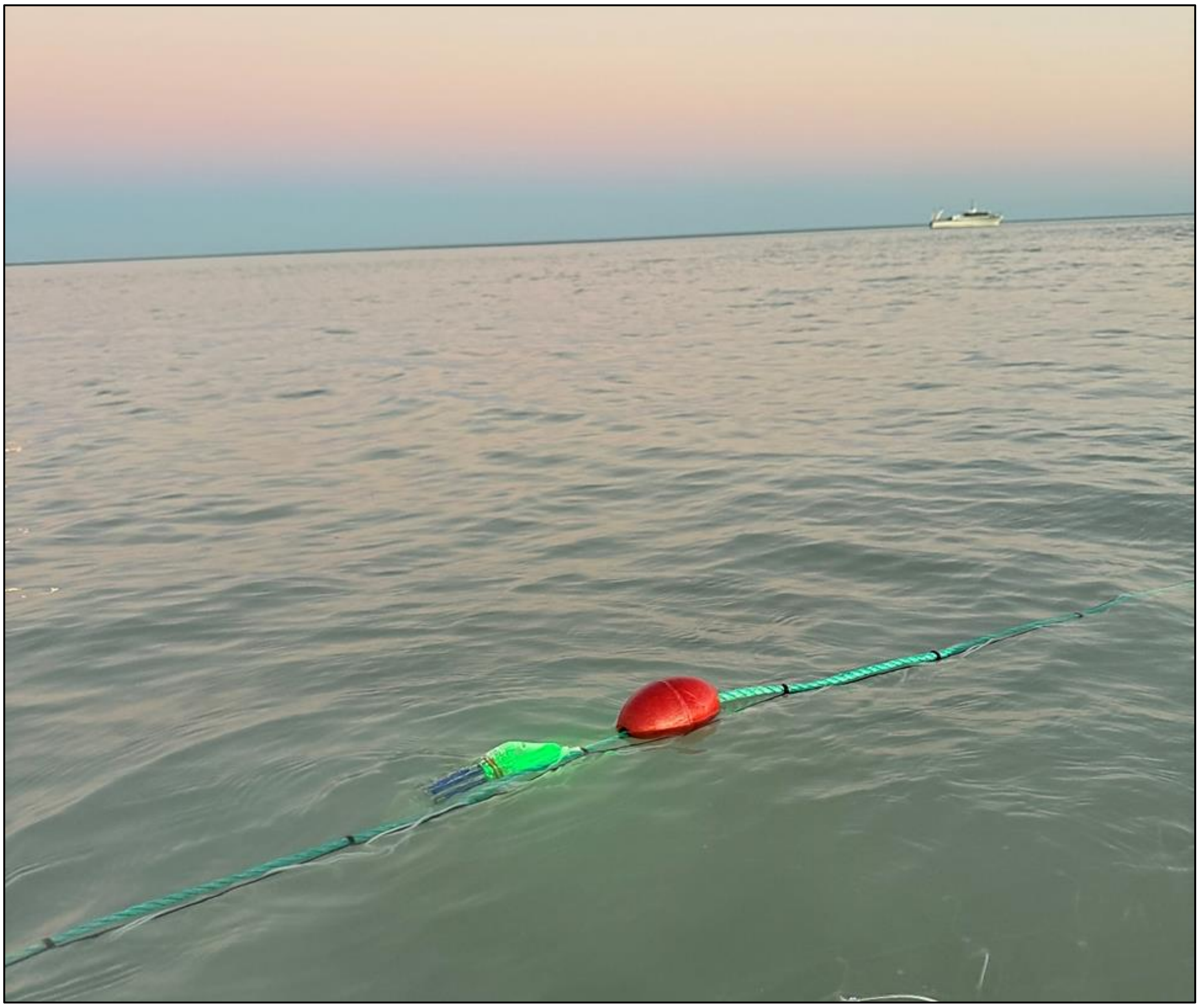
Prepared by Dr Joni Pini-Fitzsimmons, Emily Taljaard, Samuel Amini



A green LED bycatch deterrent device on a gillnet deployed in Roebuck Bay, Western Australia. Photo by Dr. Alastair Harry, Western Australia Department of Primary Industries and Regional Development.

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Executive Summary

Background

Net fisheries in northern Australia that use static monofilament nets, such as gillnets, set nets, mesh nets, and pelagic nets (herein termed gillnet fisheries), face a significant challenge in mitigating the bycatch of threatened species, particularly sharks and rays (elasmobranchs) listed under the *Environmental Protection and Biodiversity Conservation Act 1999*. These species include sawfishes, river sharks, and devil rays, which are highly susceptible to capture due to their overlap with fishing grounds and their morphological characteristics. Their limited capacity to recover from population declines, owing to slow growth, late maturity, and low reproductive rates, makes them especially sensitive to fishing pressure. As such, bycatch of these species remains an ongoing management concern, highlighting the urgent need to develop and implement effective mitigation strategies.

While bycatch reduction technologies have been successfully adopted in some Australian net-based fisheries, such as the Northern Prawn Fishery, similar advancements in gillnet fisheries are lacking. Two promising bycatch mitigation technologies have been identified for trial in Australian gillnet fisheries, based on international research and with support from industry: static green LED lights and electric deterrents. Green LED lights, designed to illuminate fishing gear, have shown success internationally in reducing bycatch across a range of taxa, including sea turtles, marine mammals, and elasmobranchs. Electric deterrents, which aim to overstimulate the electrosensory systems of sharks and rays to reduce their interactions with fishing gear, have demonstrated effectiveness in longline fisheries. Despite their demonstrated potential overseas, these technologies have yet to be tested for mitigation shark and ray bycatch in Australian gillnet fisheries.

The need for bycatch mitigation is further underscored by increasing regulatory pressure and shifting policy landscapes. Initiatives to phase out commercial gillnet fishing in the Great Barrier Reef and Gulf of Carpentaria, along with recent regulatory changes in the Northern Territory Barramundi Fishery, reflect a growing emphasis on sustainability and conservation outcomes. While mitigation technologies offer a near-term strategy to reduce bycatch within existing gillnet operations, the identification and development of viable alternative gears will be essential to ensuring the long-term sustainability and adaptability of these fisheries in a changing regulatory landscape.

Aims and Objectives

This project aimed to provide industry and managers with scientifically tested bycatch mitigation strategies for Australian gillnet fisheries while also evaluating alternative gears for the commercial Barramundi fishing. To achieve this, the project set out with two key objectives:

- **Objective 1.** Comprehensively test two bycatch mitigation devices in gillnet fisheries to provide industry and managers with scientifically robust and tested measures with the potential to be implemented throughout a variety of gillnet fisheries.
- **Objective 2.** Assess alternative gears to gillnets in the Northern Territory Barramundi Fishery. Investigating alternative gear is aimed at assessing if there are ways to achieve sustainable catches of target species while reducing or even eliminating bycatch of focal threatened species.

By taking this dual approach, the project seeks to improve current practices while assisting industry in proactively addressing regulatory shifts, to enhance both conservation outcomes and the long-term sustainability of northern Australian gillnet fisheries.

Methods and results

Bycatch Mitigation Device Trials

To address Objective 1, experimental trials were undertaken through three complementary studies: (1) aquarium trials to understand the response that the bycatch mitigation devices elicit in elasmobranchs, (2) fishery-independent trials to examine catch rates of bycatch and target species in controlled experimental field conditions using gillnets, and (3) fishery-dependent trials under normal commercial fishing operations in northern Australian commercial gillnet and pelagic net fisheries. Results showed species- and context-specific effects of Green LEDs and Electric Deterrents.

Green LEDs showed potential for deterring Sawfish, a key threatened species, in inshore fishery-independent trials using gillnets but also appeared to attract certain species in offshore fishery-dependent trials using pelagic nets, including Hammerhead Sharks (a species of conservation interest). Electric Deterrents showed promising, though inconclusive, trends, suggesting potential deterrence of Sawfish (fishery-independent) and Hammerhead Sharks (fishery-dependent). Neither device had negative impacts on key target species such as Grey Mackerel or Blacktip Sharks in offshore fishery-dependent trials using pelagic nets, although their effects on target species in inshore fishery-independent trials varied. Specifically, Green LEDs led to increased catches of Blue Threadfin while possibly deterring King Threadfin, and Electric Deterrents showed a potential increase in Barramundi catches.

The ability to reliably assess the effects of these devices on focal threatened, endangered, and protected species was limited by low sample sizes in this study, particularly in the fishery-dependent trials where only one threatened species was caught. While the trialled devices showed promise for bycatch reduction in specific contexts, the results did not demonstrate consistent or broadly applicable reductions in bycatch across fisheries or gear types. As such, the devices are not currently suitable for bycatch mitigation in gillnets, or pelagic nets, in their current form. Further research with larger sample sizes is required to optimise their design and fully assess potential impacts on target, byproduct, and bycatch species before commercial adoption should be considered.

Alternative Gear Assessment

To address Objective 2, an Alternative Gear Assessment was undertaken to provide industry with information on options to move beyond gillnetting in the future should suitable alternative gear be identified, critiqued, and tested (noting that testing was outside the scope of the project). The assessment focused on the commercial sector of the NT Barramundi Fishery, but the outcomes are applicable across all northern Australian gillnet fisheries. The Assessment consisted of two components (1) a Desktop Review to establish an evidence base for potential alternative gear options and (2) a Workshop with industry and managers to assess the practicality and feasibility of those options in the operational setting of the NT Barramundi Fishery.

The assessment highlighted strong industry interest in alternative gears, particularly passive fishing gears such as pound nets, tunnel nets, and fish pots, while also identifying key operational challenges in the specific context of the NT Barramundi Fishery, such as access arrangements and regulatory clarity. Discussions underscored the importance of gear trials, knowledge-sharing, and a structured transition strategy to support the long-term sustainability of the NT Barramundi Fishery. With recent calls to phase out gillnets within three years within the commercial sector of the NT Barramundi Fishery, regulatory clarity and investment in gear trials and investigations of emerging fishing technologies are critical. The Alternative Gear Assessment therefore provided a foundation for informed decision-making, supporting industry and fisheries managers in navigating the transition while balancing conservation and economic goals.

Recommendations

Bycatch Mitigation Devices

While this project did not find consistent or broadly applicable reductions in threatened species bycatch across fisheries or gear types resulting from use of bycatch deterrent devices, promising trends observed for vulnerable species such as sawfish and hammerhead sharks highlight the need for further investigation. Therefore, before commercial adoption is considered, we make the following recommendations for future work:

- **Expand Field Trials**: Conduct larger-scale trials across different fisheries and seasons to strengthen results and assess long-term deterrent effectiveness.
- **Optimise Device Design**: Refine Green LED and Electric Deterrent configurations and specific attributes to improve their efficacy, particularly for specific threatened species, to maximise efficacy.
- **Evaluate Operational Feasibility**: Assess the practicality and cost-effectiveness of the tested devices in commercial operations, including durability, ease of integration, and economic impacts.
- **Enhance Collaboration**: Foster a co-design approach between researchers, fishers, and managers to ensure future research is both scientifically robust and practically relevant, with industry-driven trials.

Alternative Gears

- **Clarify Regulatory and Policy Arrangements**: Clarify legislative and policy frameworks to support the transition from gillnets in the NT Barramundi Fishery.
- **Conduct Pilot Trials and Field Testing**: Conduct trials of supported alternative gears (e.g., pound nets, tunnel nets, fish pots) and explore emerging techniques to assess their viability, selectivity, threatened species interactions and mitigation, commercial potential, and social acceptability.
- **Implement Sustainable Use of Gillnets**: Implement best practices for gillnet usage during the transition, such as reduced soak times, increased net attendance, and monitoring.

This project provides a foundation for reducing bycatch while ensuring the viability of commercial gillnet fisheries in northern Australia. The findings reinforce the importance of continued research, adaptive management, and collaboration between industry, regulators, and researchers. Advancing bycatch mitigation technologies and alternative gear options will be essential for balancing conservation and economic goals in northern Australia’s gillnet fisheries.

Introduction

Mitigating the bycatch of threatened species in Australian net fisheries is a major management challenge. Australian prawn trawl gear is a well-documented example of how the testing and implementation of bycatch reduction devices has resulted in the significant reduction in the bycatch of non-target species, including threatened species (e.g., Laird et al. (2020)). However, devices or modifications to reduce bycatch in static monofilament nets, referred to in this report as 'gillnets', but includes gillnets, set nets, mesh nets, and pelagic nets, are far less well studied. Where the deployment of these nets overlaps with the habitat of threatened species, bycatch of these species can occur, creating a significant management issue. Within northern Australian gillnet fisheries, bycatch of threatened and/or migratory sawfishes, river sharks, and devil rays listed under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) (herein Threatened, Endangered, and Protected Species, TEPS) is an on-going issue (Jacobsen et al., 2021; NT Government, 2020, 2024) requiring evidence-based interventions.

Northern Australia holds the most significant remaining populations of sawfishes and river sharks globally (DCCEEW, 2015), but these important species form the most numerous TEPS bycatch in northern Australian gillnet fisheries (Jacobsen et al., 2021; NT Government, 2020, 2024). This is primarily due to the spatio-temporal overlap between key habitats and migratory pathways for these species and key fishing grounds (Constance et al., 2024; Field et al., 2013), as well as their increased susceptibility of entanglement, particularly for sawfishes with their toothed rostrum. Within these fisheries, the target species are harvested at sustainable levels with high-quality seafood product providing important economic contributions locally and nationally (FRDC, 2023b). Therefore, mitigating the on-going bycatch of TEPS is arguably the most significant challenge facing these fisheries.

Through the Northern Territory (NT) Barramundi Fishery Management Advisory Committee (BFMAC), members of our project team were involved in a review of potential bycatch mitigation options for the NT Barramundi Fishery (ca. 2023). This process considered the latest scientific research in bycatch mitigation, bycatch levels in the fishery, ecological risk assessment outcomes, and how the fishery operates, to short-list bycatch mitigation options to trial (BFMAC TEPS Working Group, unpub. data). Among the shortlisted bycatch mitigation options, static LED lights and electric deterrents emerged as promising technologies based on international research.

Static green LED lights are designed to illuminate fishing gear and exploit the visual senses of bycatch species, while not impacting target species. Notably, static green LED lights are the only bycatch mitigation devices shown to date to significantly reduce bycatch in gillnets for all four main bycatch species groups – seabirds, marine mammals, marine turtles, and elasmobranchs (Lucas & Berggren, 2023). Research effort into the use of green LEDs in gillnets has been focussed primarily on sea turtles. In their pioneering work on visual deterrents for sea turtles in gillnets, Wang et al. (2010) noted a 40% reduction in sea turtle bycatch using green LEDs with a negligible effect on target catch. Likewise, Ortiz et al. (2016) and Bielli et al. (2020) found a 64% reduction in green turtle and 75% reduction in all turtle bycatch in Peruvian gillnet fisheries, respectively. Also in Peruvian gillnets, green LEDs have been shown to reduce seabird bycatch by >80% in two separate studies (Bielli et al., 2020; Mangel et al., 2018). In one of these studies, green LEDs resulted in over 65% reduction in small cetacean catch per unit effort (CPUE) in both surface driftnets and bottom gillnets (Bielli et al., 2020). For elasmobranchs, testing of green LEDs for reducing bycatch in gillnets has been limited; however, Senko et al. (2022) demonstrated a 95% reduction in shark and ray bycatch in trials of green LEDs on bottom-set gillnets in Mexico.

In contrast, the utility of electric deterrents for reducing bycatch of TEPS is only recently being tested and understood. Despite this, electric deterrents are considered one of the most promising bycatch reduction technologies for elasmobranchs due to the unique electrosensory capabilities of this group (Lucas & Berggren, 2023). Elasmobranchs have a highly specialized electrosensory system known as the Ampullae of Lorenzini, which is concentrated around the mouth and snout, and allows them to detect weak electric fields in their environment, particularly those produced by prey. Electric deterrents are designed to overstimulate this sensory system, creating an unpleasant sensation that discourages approach without causing harm to the animal. With this in mind, electric deterrent technology was first developed for human protection from sharks and has since included the use of ferrite and rare earth magnets, electropositive metal alloys, electrode arrays, and Selective Magnetic and Repellent-Treated (SMART) hooks (see Lucas and Berggren (2023) for review). Most recent developments have focussed on continuous or pulsed electric signals to trigger aversive responses. For instance, captive Sandbar Sharks (*Carcharhinus plumbeus*) have been deterred from feeding using electric fields (Howard et al., 2018), and captive Largetooth Sawfish (*Pristis pristis*) have shown aversive behaviours in response to pulsed electric fields (Abrantes et al., 2021). In field trials, a pulsed electric device (Ocean Guardian Shark Shield® Freedom 7; www.ocean-guardian.com) prevented >80% of predation attempts on baits for a number of ray species within oyster leases (Raoult et al., 2023). In a fisheries context, trials of a pulsed electric deterrent (SharkGuard, Fishtek Marine) on pelagic longlines (hooks) off France demonstrated a 91% reduction in Blue Shark (*Prionace glauca*) bycatch and a 71% reduction in Pelagic Stingray (*Pteroplatytrygon violacea*) bycatch, with no impact on catches of target Bluefin Tuna (*Thunnus thynnus*) (Doherty et al., 2022). To our knowledge, electric deterrents have not been explored as a bycatch deterrent for net-based fisheries to date.

Neither green LED lights nor electric deterrents have been tested as bycatch mitigation devices for elasmobranch bycatch in Australian gillnet fisheries. Based on the promising results of overseas studies highlighted above, there is significant interest from commercial gillnet fishers in northern Australian waters in testing these two devices to potentially reduce bycatch of threatened and protected elasmobranchs, and as such experimental trials under local conditions are needed to assess their efficacy in this context.

At the same time, commercial gillnet use in Australian waters is facing increasing scrutiny and regulatory pressure due to impacts on threatened species, reflecting a broader shift toward more sustainable fishing practices. As such, mitigation efforts alone may not be sufficient to ensure the long-term sustainability of these fisheries. In recent years, significant steps have been taken to phase out commercial gillnet use, particularly in inshore waters. The Australian and Queensland governments have committed to phasing out commercial gillnet fishing in the Great Barrier Reef World Heritage Area by mid-2027, allocating over $160 million for licence buybacks and the transition to more sustainable practices (Queensland Government, 2024a). Gillnet-free areas were also implemented in the Gulf of Carpentaria in May 2024 as part of consultation on the Gulf of Carpentaria Inshore Fishery (Queensland Government, 2024b). In 2024, the Northern Territory government also announced plans to phase out commercial gillnet fishing for Barramundi (Houlbrook-Walk & Fitzgerald, 2024).

These developments underscore that while trialling and implementing bycatch mitigation technology plays a crucial role in reducing the impact of gillnets on TEPS, they may not be sufficient to fully address growing concerns or meet future regulatory expectations. As long as gillnets remain in use, it is essential to continue improving their selectivity and reducing bycatch through targeted mitigation strategies. At the same time, there is a need to look ahead and explore alternative fishing gears that can support industry adaptation and long-term sustainability. By taking a dual approach of enhancing current practices while preparing for future transitions, we can help ensure that these fisheries remain both environmentally responsible and economically viable.

Aims and objectives

The primary aim of this project was to provide industry and managers with proven options to assist implementation of TEPS mitigation strategies in northern Australian gillnet fisheries, with a focus on EPBC Act listed sharks and rays. To achieve this, the project set out with two key objectives:

- **Objective 1.** Comprehensively test two bycatch mitigation devices in gillnet fisheries to provide industry and managers with scientifically robust and tested measures with the potential to be implemented throughout a variety of gillnet fisheries.
- **Objective 2.** Assess alternative gears to gillnets in the Northern Territory Barramundi Fishery. Investigating alternative gear is aimed at assessing if there are ways to achieve sustainable catches of target species while reducing or even eliminating bycatch of focal threatened species.

In partnership with industry, trials of bycatch mitigation devices aimed to assess the effectiveness of the devices to elicit a response in shark and ray bycatch species, their ability to reduce TEPS bycatch levels, and their impact on target species. The assessment of alternative gear types aimed to provide options for alternative gears to industry to assist in transitioning from commercial gillnets to fishing gear with lower threatened species bycatch levels in the future.

Expected outcomes

The project was expected to deliver six key outcomes:

- **Outcome 1. Understanding the response of sharks and rays to deterrents.** Through the aquarium trials under Objective 1, we analysed how sharks and/or rays respond to the selected Green LED lights and Electric Deterrent in an experimental setting. Given the visual and electro-sensory systems of sharks and overseas studies, we hypothesised that sharks/rays will respond to these deterrents under controlled testing conditions.
- **Outcome 2. Understanding the bycatch reduction capabilities of deterrents.** Through both fishery-independent and fishery-dependent trials in the field under Objective 1, we delivered an evaluation of the effectiveness of the two mitigation devices. Effectiveness was assessed in two contrasting fisheries contexts: 1. turbid inshore estuarine/coastal waters characteristic of inshore Barramundi fishing where sawfish and river shark bycatch are of greatest concern and 2. clearer offshore marine waters characteristic of pelagic net fishing for Mackerel and sharks, where sawfish and devil ray bycatch are an issue.
- **Outcome 3. Understanding alternative gear options for commercial Barramundi fisheries.** Reviewing and workshopping alternative gears under Objective 2 provided industry information on options to move beyond gillnetting in the future. We brought together industry representatives, alongside managers, and researchers to assess alternatives. While the initial focus considered gears for the NT Barramundi Fishery, this outcome has applicability across WA, NT, and Qld.
- **Outcome 4. Enhanced capability within the commercial sector to innovate and trial mitigation measures and assess alternative gear.** Collaborations, partnerships, communication, and engagement through this project highlight threatened species bycatch issues in northern Australian gillnet fisheries and showcase industry innovation to find solutions. Through direct trials on commercial fishing vessels and workshops, we aimed to train industry members on deterrent deployment and operation.
- **Outcome 5. Reduction of interactions with threatened species in northern Australia.** If the success of the two deterrents overseas can be translated to northern Australian conditions and their implementation advanced, the ultimate outcome for this project will be the reduction in bycatch of several threatened species.
- **Outcome 6. Identify the barriers and solutions to uptake of mitigation methodologies by industry.** Through industry engagement, we identify key challenges to the uptake of bycatch mitigation strategies and explore solutions that enhance feasibility and practicality. This will provide a foundation for future implementation and policy development.
- **Outcome 7. Identify methods of including relevant Indigenous communities.** This project explored ways to involve relevant Indigenous communities in developing and implementing bycatch mitigation strategies. Through directed engagement, we aimed to ensure that Indigenous perspectives, fishing

interests, and management priorities are meaningfully incorporated into decision-making and future directions.

Report Structure

This report is structured around the 2 project objectives. Objective 1 is addressed through the "Bycatch Mitigation Device Trials" section and includes an overview of the selection process of bycatch mitigation devices for trialling, and the methods, results and conclusions for the 3-phases of the device trials (Aquarium Trials, Fishery-Independent Trials, and Fishery-Dependent Trials). Objective 2 is addressed through the "Alternative Gear Assessment" section.

Bycatch Mitigation Device Trials

Device Selection

The selection of bycatch mitigation devices for trial was guided by a structured review process conducted by the Northern Territory Barramundi Fishery Management Advisory Committee (BFMAC) in 2023. A TEPS Working Group, comprising threatened species experts, commercial fishers, government research scientists, and fisheries managers, assessed a range of mitigation measures based on scientific evidence, ecological risk assessments, and fishery-specific operational considerations. The group shortlisted potential mitigation approaches using a decision matrix that categorised options based on cost, feasibility, and effectiveness. From this process, two mitigation devices, static green LED lights (NetLight) and electrical deterrents (SharkGuard) (Figure 1), were identified as the highest priority for field testing in northern Australian gillnet fisheries.

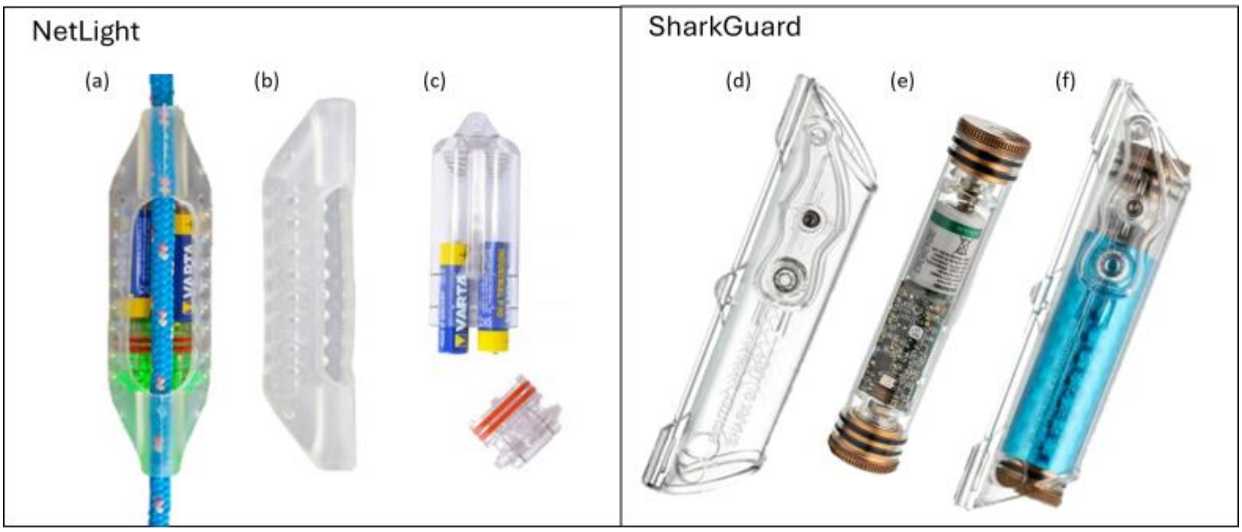


Figure 1. NetLight green LED (a-c) and SharkGuard electric deterrent (d-f) used in this project. Both provided by Fishtek Marine. NetLight: (a) NetLight in outer casing affixed to rope with LED illuminated; (b) TPE co-polymer rubber casing; (c) NetLight device showing components (165 mm x 47 mm x 37 mm). SharkGuard: (d) polycarbonate casing; (e) SharkGuard device (100 mm x 20 mm) showing inner circuitry; (f) SharkGuard in casing.

The NetLight (FishTek Marine, UK) is a waterproof, submersible LED light designed to illuminate fishing gear and increase its visibility. NetLights come in either green or white lights, and constantly on or flashing. For this study, the static green (500 nm) LED configuration was selected, as previous research has shown this wavelength when constantly on to be most effective in reducing bycatch for a range of species (Lucas & Berggren, 2023). Each unit in the rubber casing measures 165 mm × 47 mm × 37 mm, weighs 25 g in water, and is depth-rated to 1200 m. The light is powered by two AA alkaline batteries, activated upon water immersion, and has an in-water battery life of 500 hours in constantly on mode. The area the light illuminates is influenced by positioning on the fishing gear, environmental conditions, particularly ambient light levels and turbidity, as well as the visual sensitivities of focal species regarding light level, contrast, and colour detection.

The SharkGuard (MKIV, FishTek Marine, UK) is a prototype electric deterrent that generates a pulsed electric field designed to overwhelm the electrosensory systems of sharks and rays. The device is powered by a 3.6 V lithium thionyl chloride battery and emits a 30 V electrical pulse lasting 1.5 milliseconds every 2 seconds (0.5 Hz). The device automatically activates upon immersion and has an in-water battery life of 65 hours. The device (without case) measures 100 mm × 20 mm, weighs 46 g in seawater, and is depth-rated to 1000 m. The effective range is influenced by both the power of the emitted electrical pulses and the species-specific sensitivities of elasmobranchs to this stimulus. In their trials of SharkGuard in a longline fishery, Doherty et al. (2022) determined an effective range of 12.5 m based on three-dimensional finite element analysis (FEA) and the median electrical stimulus threshold for pelagic stingrays (*Pteroplatytrygon violacea*).

For this project, experimental trials were undertaken through 3 complimentary studies: (1) aquarium trials to understand the response that the devices elicit in elasmobranchs; (2) fishery-independent trials to examine catch rates of bycatch and target species in controlled experimental field conditions using gillnets; and (3) fishery-dependent trials under normal commercial fishing operations in northern Australian commercial gillnet fisheries. By testing the responses of elasmobranchs in captivity using a small number of individuals, we can further refine the deployment of devices on fishing gear during the field trials to allow for a scientifically robust evaluation of the devices for commercial gillnet fisheries.

Ethics and permitting

All research for this project was conducted under relevant animal ethics approvals and research permits. The use of animals for the Aquarium Trials, Fishery-Dependent Trials, Fishery-Dependent Trials was approved by the Charles Darwin University Animal Ethics Committee (Project A24001). Activities for the Aquarium Trials was approved under Queensland General Fisheries Permit No. 269384 and Queensland Marine Park Permit Authority No. P-MPP-100630883. Activities conducted for the Fishery-Independent Trials in Western Australia were conducted under research permits held by WA Department of Primary Industries and Development and in the Northern Territory under Special Permit No. S17/3609. Activities conducted in the Northern Territory for the Fishery-Dependent Trials were conducted under Special Permit No. S17/3622.

Aquarium Trials

Methods

These trials aimed to understand how elasmobranchs respond to the selected bycatch mitigation devices in a controlled environment. We hypothesised that given the unique visual and electro-sensory systems of elasmobranchs (Hart, 2020; Sisneros & Tricas, 2002) and evidence from overseas studies (e.g., Doherty et al. (2022); Lucas and Berggren (2023); Senko et al. (2022)), elasmobranchs would respond to these deterrents by being deterred from coming into contact with an experimental net. Due to the rarity of threatened species, and logistical constraints involved in capture and housing for species such as sawfishes and Mobulid rays, these trials involved common elasmobranch species to understand the potential effects of the deterrents on elasmobranchs generally.

Study location

This study took place at the University of Queensland Moreton Bay Research Station (MBRS), on North Stradbroke Island, Queensland, between 8 October - 8 November 2024. Elasmobranchs used for the experimental trials were captured locally from within the Moreton Bay Marine Park (Figure 2).

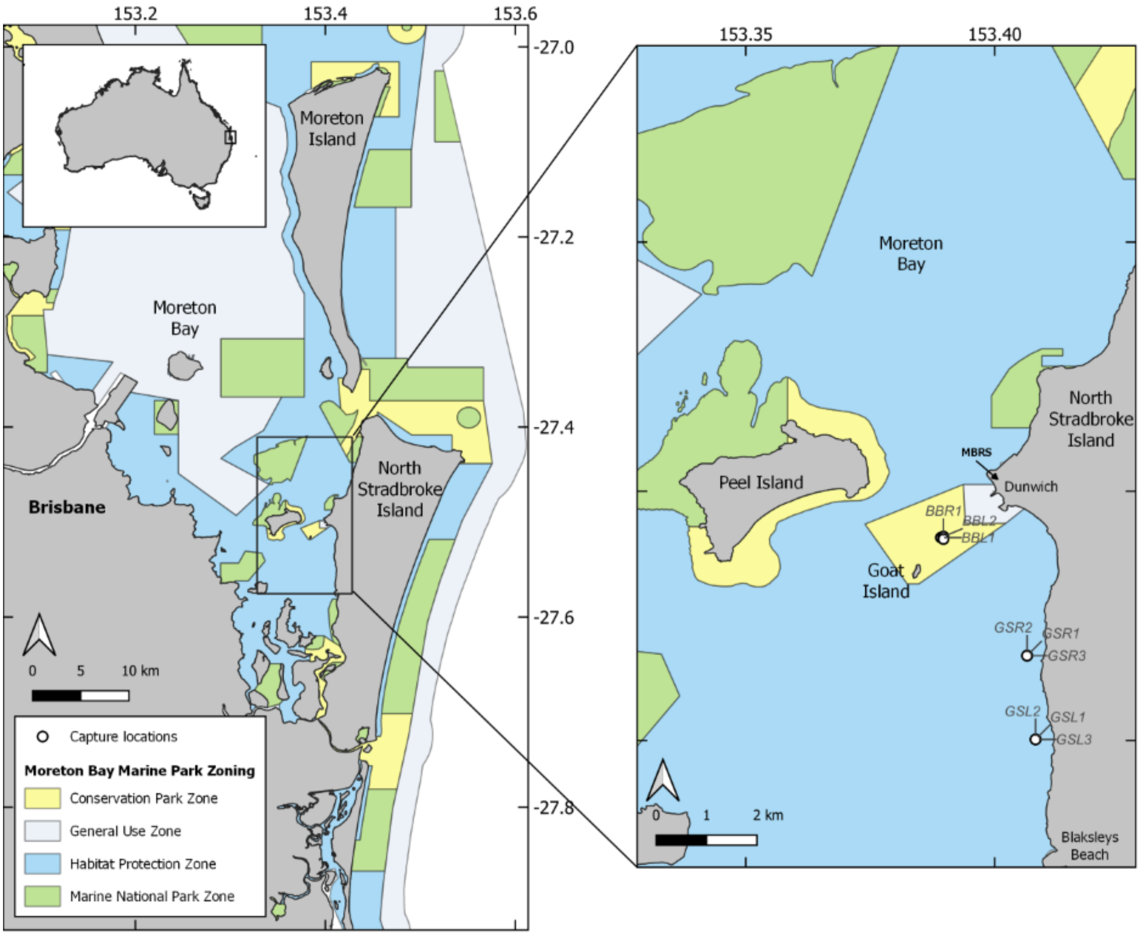


Figure 2. Map of the Moreton Bay Marine Park, Queensland indicating fishing locations for elasmobranchs to undergo aquarium trials. MBRS = Moreton Bay Research Station.

Animal capture and housing

Two cohorts of elasmobranchs were captured for experimental trials. The first cohort consisted of five Giant Shovelnose Rays (*Glaucostegus typus*) captured in collaboration with commercial tunnel net fishers on sandflats between Dunwich and Blaksleys Beach (-27.5498 E, 153.4082 S) on 15/10/24 (n = 3) and 16/10/24 (n = 2). The second cohort included three Brownbanded Bamboo Sharks (*Chiloscyllium punctatum*) captured via hook-and-line on 27/10/24 (n = 2) and 1/11/24 (n = 1).

Captured animals were placed in an aerated transport tub (~100 L) aboard a research vessel. Hooks were promptly removed from sharks, and all animals underwent a brief workup, including species confirmation, length measurements, sex determination, and fin clips for individual identification. Water in the transport tub was periodically exchanged enroute to the aquarium facility to maintain oxygenation and minimize stress.

Animals were transported to MBRS aquarium facilities, consisting of a 20,000 L recirculating saltwater system with a 2,500 L sump, sourced from adjacent Moreton Bay. Acclimation to the system on arrival involved gradual water exchanges to equalize pH, salinity, and temperature before placement in a 9,000 L holding tank (3.4 m W x 1.1 m D) for a 3-day acclimation period.

Daily monitoring included assessments of body condition, swimming, and feeding behaviour. Water quality (temperature, pH, salinity, dissolved oxygen) was checked daily, with periodic ammonia, nitrate, and nitrite tests to monitor waste buildup in the system. Animals were fed daily to satiation: Shovelnose Rays in the morning and afternoon, Bamboo Sharks at night. Holding tanks contained sand and artificial seagrass (Shovelnose Rays) or PVC pipes and shade cloth (Bamboo Sharks) for habitat. Following trials, animals were released at their capture sites.

Behavioural Trials

Trials were conducted in a 2,500 L circular tank (2 m W x 0.8 m D) with artificial seagrass in the centre to obstruct view of the experimental net. A gentle water current moved water in a circular motion in the tank to encourage swimming. The experimental net consisted of a horizontal arm with vertical monofilament lines with weights at the end (Figure 3) to mimic a gillnet, whilst allowing free movement of animals through the net (if not deterred). Three treatments were tested: (i) control net (monofilament strands only), (ii) Electric Deterrent net (SharkGuard affixed at mid-depth), and (iii) Green LED net (green NetLight affixed at the surface, lit end facing downward). A GoPro was mounted overhead to record all trials.

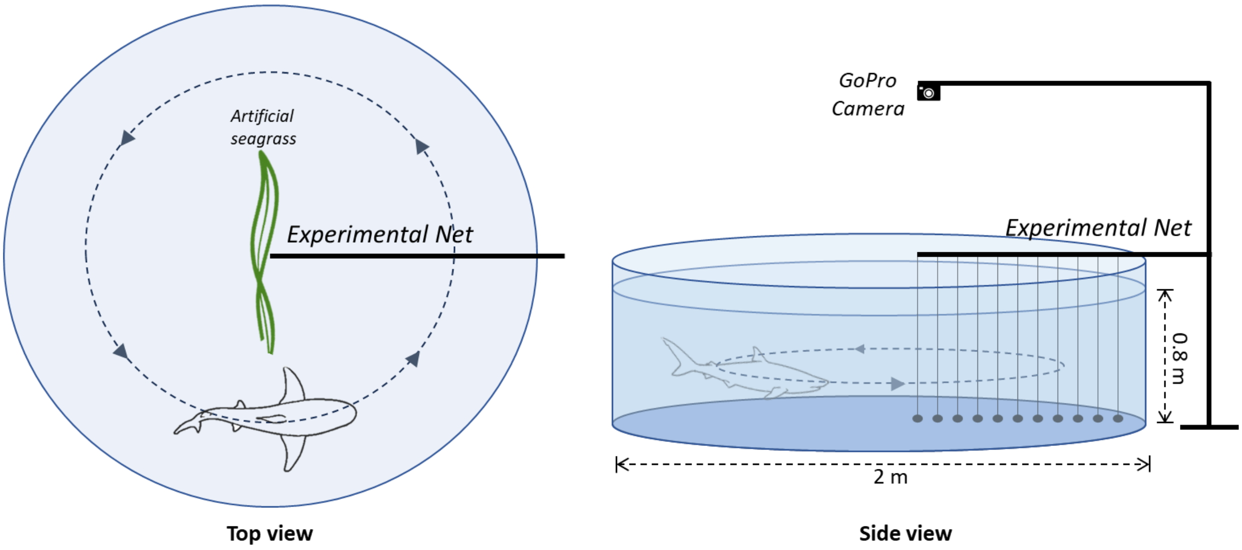


Figure 3. Schematic of experimental set up for the Aquarium Trials.

Each animal underwent up to six randomised trials, with a total of one per day to mitigate habituation and handling stress. The order in which animals underwent trials in a given day were also randomised. Trials for Shovelnose Rays began an hour after morning feeding, while Bamboo Shark trials were conducted in the evening before feeding, when they were most active.

Animals were transferred by hand net to the trial tank and given 15 minutes to acclimate. Once positioned on the opposite side of the tank with an obscured view from the artificial seagrass, the experimental net was introduced, initiating the trial. Shovelnose ray trials lasted 10 minutes, encompassing multiple interactions, while bamboo shark trials ended after the first interaction. For all animals, only the first interaction was assessed. After trials, animals were returned to the holding tank and observed for 15 minutes to ensure no lasting impacts from the trials.

An observer recorded trial start/end times, interaction start/end times, and interaction types. Interactions were categorised as follows:

1. Swimming through net: making perpendicular contact with the net and allowing its body to pass through the test net;
2. Turn in net: making contact with the net and turning, while remaining in contact with the net;
3. Side on and through: approaches parallel to the net and then passing through;
4. Turn at net: the nose makes contact with the net and animal turns away;
5. Turn before net: approaches net perpendicular and turns away before making contact;
6. Side on, turn away: approaches parallel to the net and turns before making contact with the net; and
7. Swim around net: swims around the net (between net and seagrass) without making contact.

Interactions 1–4 were considered "not deterred," as contact with a net in commercial settings could lead to entanglement. Interactions 5–7 were classified as "deterred," indicating effective avoidance of the net.

Data Analysis

Animal interactions with the experimental nets were assessed by calculating the proportion of each interaction type to characterise how the animals responded to each experimental treatment (Green LED, Electric Deterrent, or control). Second, the number of Deterred vs Not Deterred interaction types were compared using a Fisher's Exact Test (for small sample sizes) to determine if there was a statistical difference between treatment types.

Results

Interaction types & deterrence

Shovelnose Rays

In the control trials, all Shovelnose Rays either swam through or turned in the net (Table 1). There was greater variation in interactions with the experimental nets with deterrent devices attached. In the Electric Deterrent treatment, the most common interaction was swimming through the net (60%), followed by turning in the net (20%), with only one instance of a ray turning away before reaching the net. In contrast, for the Green LED treatment, the most frequent interaction was turning before the net (50%), followed by swimming through the net (30%) and moving side-on before swimming through (20%).

A Fisher's exact test revealed a significant difference in deterrence among treatments ($p = 0.027$). Pairwise comparisons indicated a significantly higher proportion of deterred interactions for the Green LED treatment compared to the control ($p = 0.032$), while the Electric Deterrent did not significantly differ from either the control ($p = 1.000$) or the Green LED ($p = 0.141$). These findings suggest that Green LEDs may be more effective than no treatment in deterring shovelnose rays, whereas the Electric Deterrent showed no clear effect. However, Shovelnose Rays showed an equal number of deterred and not deterred responses for Green LED trials.

Table 1. Proportion of time (%) each interaction was observed for experimental trials of Control, Electric Deterrents and Green LEDs for Giant Shovelnose Rays. Colours highlight most frequent (green) to least frequent (red) interactions observed for each Treatment. n= the number of trials for each treatment.

	Not Deterred				Deterred			
Treatment	Swim through net	Turn in net	Side on and through	Turn at net	Turn before net	Side on, turn away	Swim around net	n
Control	50	50	0	0	0	0	0	10
Electric Deterrent	60	20	10	0	10	0	0	10
Green LED	30	0	20	0	0	50	0	10

Brownbanded Bamboo sharks

For Bamboo Sharks, interactions were generally similar across treatments (Table 2). The most common response in all trials was swimming through the net, followed by turning at the net or within it. Only one trial recorded a deterrent response, where a shark swam around the net in an Electric Deterrent trial. A Fisher's exact test found no significant difference in deterrence among treatments ($p = 0.725$). These results suggest that neither deterrent device had a significant effect on Bamboo Shark behaviour; however, sample sizes were small ($n = 5$ trials per treatment).

Table 2. Proportion of time (%) each interaction was observed for experimental trials of Control, Electric Deterrents and Green LEDs for Brownbanded Bamboo Sharks. Colours highlight most frequent (green) to least frequent (red) interactions observed for each Treatment. n= the number of trials for each treatment.

	No deterred				Deterred			
Treatment	Swim through net	Turn in net	Side on and through	Turn at net	Turn before net	Side on, turn away	Swim around net	n
Control	60	0	0	40	0	0	0	5
Electric Deterrent	40	20	0	20	0	0	20	5
Green LED	60	20	0	20	0	0	0	5

Conclusions

The Aquarium Trials evaluated the responses of two elasmobranch species to monofilament nets equipped with Green LED lights or Electric Deterrents and a control. Interaction patterns varied between species and treatments. Statistical analyses suggest that Green LEDs may be more effective at deterring Shovelnose Rays from entering nets than no treatment, but responses were equally spread between deterred and not deterred for Green LED trials. Neither device demonstrated a significant deterrent effect for Brownbanded Bamboo Sharks.

Limitations

This study faced several limitations, primarily related to sample size constraints. The original study design aimed to include 12 individuals of a single species, ideally a small-bodied Carcharhinid shark, given their prevalence as target and bycaught species in northern Australian commercial fisheries. Fishing efforts for this study resulted in no Carcharhinid sharks being captured, and instead trials were first conducted with five Shovelnose Rays. To increase the sample size, Brownbanded Bamboo Sharks were added as a secondary species due to their local availability and ability to tolerate captivity. However, logistical constraints limited the number of trials, particularly for Bamboo Sharks ($n = 5$ per treatment), which reduces the statistical power of the findings. Additionally, the small number of individuals tested per species means that individual variation in behaviour may have influenced the results.

Recommendations and Future Research

Despite low sample sizes, the increased potential deterrence effect of Green LEDs on Shovelnose Rays warrants further investigation of this technology for elasmobranch bycatch mitigation. Future studies should:

- Conduct trials with larger sample sizes to improve statistical power and generalisability.
- Include additional species, particularly Carcharhinid sharks, to assess broader efficacy on species that interact with focal fisheries.
- Test deterrents in field conditions to evaluate effectiveness under natural environmental variability.

Expanding research efforts in these areas will provide stronger evidence for the application of visual and electric deterrents in reducing bycatch of elasmobranchs in commercial fisheries.

Fishery-Independent Trials

The Fishery-Independent trials aimed to compare catch rates of target and bycatch fishes, including elasmobranchs, in gillnets with and without the bycatch deterrent devices in controlled field conditions. These trials occurred in waters reflective of fishing grounds for inshore fisheries targeting Barramundi (intertidal), and therefore the results are discussed within this context with respect to target, byproduct and TEPS interactions.

Methods

Study location

The Fishery-Independent trials took place in the Yawuru Nagulagun Marine Park (Roebuck Bay), off Broome on the coast of the Kimberley region of Western Australia, in July and September 2024 (Figure 4) in partnership with the Western Australian Department of Primary Industries and Regional Development (WA DPIRD) and Yawuru Rangers. Roebuck Bay is a tropical marine embayment characterised by extensive intertidal mudflats and bordered by mangroves intersected with numerous creeks. The bay is subject to significant tidal fluctuations, with a range spanning from 1 m during neap tides to a peak of 10.5 m during spring tides. These tidal movements expose approximately 160 km² of mudflats, covering ~45% of the total bay area.

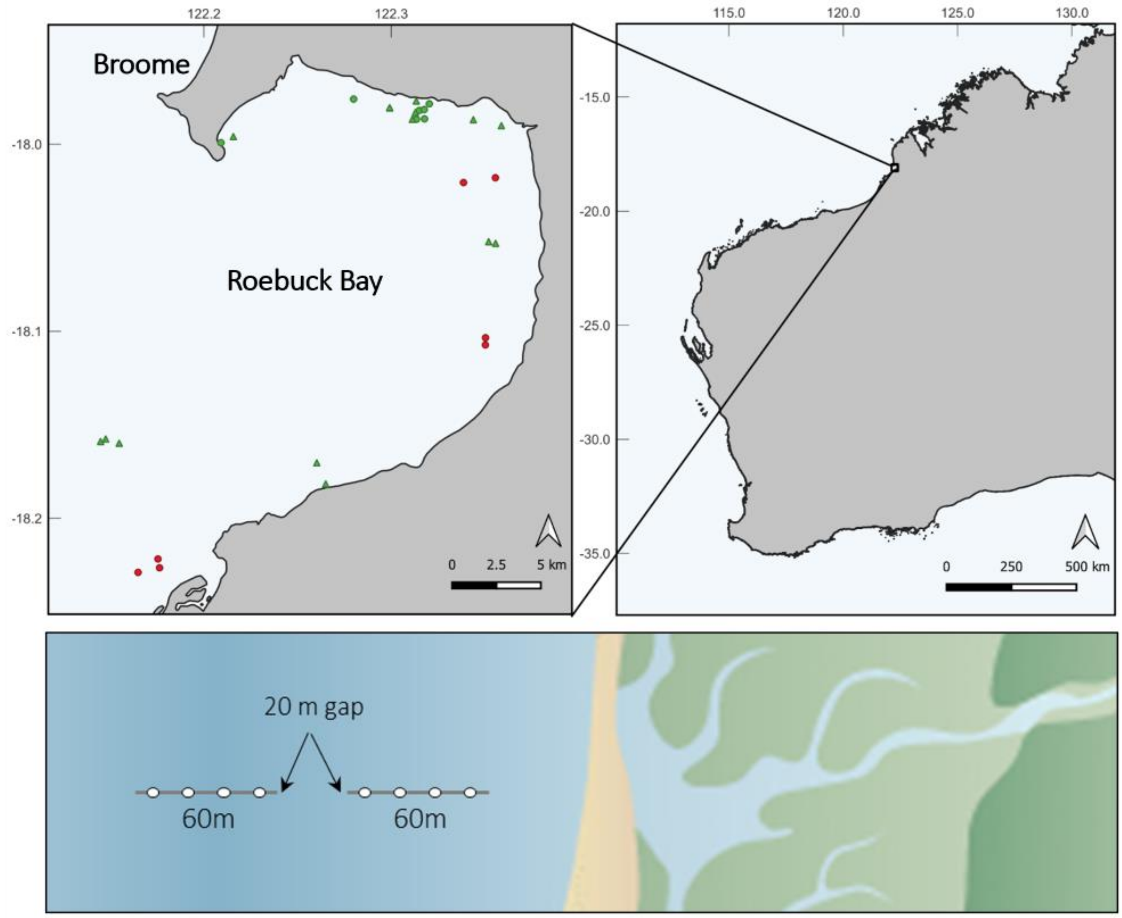


Figure 4. Top: Map of the study location and paired net deployments for the Fishery-Independent Trials in Roebuck Bay, Western Australia. Each icon represents a single paired net deployment. Circles (●) = July deployments, triangles (▲) = September deployments; green icons = LED deployments, red icons = Electric deterrent deployments. Bottom: Diagram showing the positioning of paired gillnets on intertidal mudflats.

Trials were also attempted in Bynoe Harbour in the Northern Territory (August 2024), but were discontinued due to extremely low catch rates despite comparable fishing effort to the Western Australian trials. The results of these Northern Territory Trials are not considered further for this study.

Experimental Trials

Trials involved the deployment of paired 60 m gillnets (6.5' mesh, 25 mesh deep) end to end, perpendicular to the shoreline with a spacing of 20 m (Figure 4). One net served as a Control (no devices), while the Treatment net had either Green LEDs or Electric Deterrents attached at 5 m intervals along the floatline, starting 2.5 m from each end. A device spacing of 5 m was chosen to maximise device coverage of the net while minimising the number of required devices. A 20 m net spacing was chosen to reduce potential interactions between Control and Treatment nets. The position of the Control and Treatment net was alternated between deployments. Deployments of the Green LED net pairs were only conducted in low-light periods (evenings, nighttime, or early morning) to maximise illumination of the nets, while Electric Deterrent deployments occurred exclusively during daylight hours.

Nets were deployed 1 to 1.5 hours preceding or following high or low tide to capture fish movement across the mudflat with tidal movements while avoiding periods of high flow experienced in the middle of the tidal cycle. Nets were left to soak for approximately 1 hour before being retrieved. All individual animals caught during the trials were recorded, measured, sexed, and released on site.

Data Analysis

Overall trends for bony fishes and elasmobranchs

To investigate overall trends in catches for bony fishes and elasmobranchs between net pairs, aggregated bony fish and aggregated elasmobranch catch data were compared using generalised linear mixed models (GLMM) (4 models: elasmobranchs for Green LED net pairs, elasmobranchs for Electric Deterrent net pairs, bony fishes for Green LED net pairs, bony fishes for Electric Deterrent net pairs). Aggregated catches consisted of all bony fish and all elasmobranchs caught in each net within a net pairing. The models were fit using the *glmmTMB* package in R and specified as follows:

$$n.\ animals \sim Treatment + offset(Effort) + (1|Set\_id)$$

where, *n. animals* represents to total number of individual animals for a given group, *Treatment* is the treatment being tested (Green LED or Control, or Electric Deterrent or Control), and *Effort* (soak time in hours) is included as an offset to account for differences in sampling effort. *Set_ID* is included as a random factor to account for the paired nature of the data. As the model used count data, a Poisson distribution with a log link was used. Model fit was assessed using AIC and likelihood ratio tests and residual diagnostics were used to check for overdispersion, uniformity, and zero inflation.

There were insufficient replicates for Electric Deterrent paired net deployments to use a GLMM to compare Aggregated Bony Fish or Aggregated Elasmobranch catches. Instead, paired t-tests were used to compare the mean Catch Per unit Effort (CPUE) between net pairs (Control vs Electric Deterrent) for each group, followed by calculation of effect size using Cohen's d. CPUE was calculated for each net within a net pairing as number of animals caught divided by soak time (in hours). All analyses were conducted in R (version 4.3.3).

Species-specific trends in catches

To investigate whether there were any species-specific responses, species caught most frequently across net pairs and species of commercial and conservation interest were selected for statistical analysis. For fishery target bony fish species this included Barramundi, Blue Threadfin, and King Threadfin. For elasmobranchs, this included Blacktip Sharks (grouped) as targets in pelagic net fisheries, Graceful, Nervous and Pigeye Sharks as common byproduct species in commercial gillnet fisheries, Whaler Sharks (grouped) as common catches in commercial gillnet fisheries, and Sawfish as key TEPS for gillnet fisheries.

For selected species and groups, catch per unit effort (CPUE) was calculated for each net within a net pairing as number of animals caught divided by soak time (in hours). Paired t-tests were then used to compare the mean CPUE between net pairs (Control vs Green LED; Control vs Electric Deterrent), followed by calculation of effect size using Cohen's d.

Results

A total of 43 paired net deployments ($n_{electric}$ = 13, n_{LED} = 30) were conducted, but several were excluded from analysis due to low catch rates (Bynoe Harbour, NT: $n_{electric}$ = 6, n_{LED} = 1), zero catches in both nets, nets drying out, soak times < 30 m (n_{LED} = 4), or deployment of LED nets during daylight hours (n_{LED} = 3). This left a 7 Electric Deterrent paired net deployments and 22 Green LED paired net deployments for further analysis.

Catch rates and composition were variable within and between Green LED and Electric Deterrent net pairings (Table 3). Among Bony Fish, Barramundi, King Threadfin, and Blue Threadfin were consistently recorded, and Elasmobranchs formed a substantial component of the catch, with Blacktip Sharks and Whaler Sharks being among the most frequently recorded. Nervous Sharks, Pigeye Sharks, and Graceful Sharks made up the bulk of the Whaler shark catch composition. Three species of Sawfish were caught across the paired net deployments; however, catches were low.

*Table 3. Mean and standard error (SE) catch per unit effort (CPUE) for all species caught during the Fishery-Independent Trials for (a) Green LED paired net deployments (n = 22) and (b) electric deterrent paired net deployments (n = 7). Fishery Target category is based on inshore Barramundi fishing (e.g., Northern Territory Barramundi Fishery) TEPS = Threatened, Endangered and Protected Species. SoC = Species of Concern. n = number of individual animals. * = grouped species.*

(a)			Control				Green LED				
Common Name	Scientific Name	Fishery Target	n	Mean CPUE	Sd	SE	n	Mean CPUE	Sd	SE	n. net pairs
Bony Fish											
Barramundi	*Lates calcarifer*	Target	11	1.716	1.610	0.657	18	2.247	1.558	0.636	9
King Threadfin	*Polydactylus macrochir*	Target	7	1.299	0.650	0.291	1	2.069			6
Grey Mackerel	*Scomberomorus semifasciatus*	Byproduct	0				1	1.132			1
Blue Threadfin	*Eleutheronema tetradactylum*	Byproduct	32	4.839	6.761	2.706	30	3.520	2.158	0.763	9
Giant Queenfish	*Scomberoides commersonnianus*	Byproduct	3	1.244	0.316	0.182	5	2.326	2.367	1.674	5
Barred Javelin	*Pomadasys kaakan*	Byproduct	1	0.789			0	0			1
Triple Tail	*Lobotes surinamensis*	Byproduct	1	0.682			2	1.278	1.118	0.791	3
Northwest Black Bream	*Acanthopagrus palmaris*	Bycatch	0				1	0.741			1
Brassy Trevally	*Caranx papuensis*	Bycatch	1	0.822			0				1
Trevally sp.		Bycatch	0				1	1.000			1
Sicklefish	*Drepane punctata*	Bycatch	3	1.166	0.357	0.206	3	1.027	0.392	0.277	5
Shieldhead catfish	*Plicofollis nella*	Bycatch	0				1	0.984	0.000	0.000	1
Dart (Undifferentiated)	*Trachinotus* spp.	Bycatch	0				5	1.752	0.781	0.451	3
Elasmobranchs											
Common Blacktip Shark	*Carcharhinus limbatus*	Byproduct	1	1.000			1	1.000			2
Australian Blacktip Shark	*Carcharhinus tilstoni*	Byproduct	1	1.000			0				1
Blacktip (Undifferentiated)	*C. limbatus, C. tilstoni.*	Byproduct	18	3.205	2.435	1.089	9	1.346	0.501	0.205	9
*Blacktip complex	*C. limbatus, C. tilstoni*	Byproduct	20	3.605	2.920	1.306	10	1.513	0.529	0.216	9
Spot-tail Shark	*Carcharhinus sorrah*	Byproduct	1	0.811			0				1
Graceful Shark	*Carcharhinus amblyrhynchoides*	Byproduct	5	1.244	0.496	0.287	11	1.115	0.367	0.130	8
Pigeye Shark	*Carcharhinus amboinensis*	Byproduct	15	3.661	3.260	1.882	9	1.571	1.023	0.458	6
Nervous Shark	*Carcharhinus cautus*	Byproduct	22	1.821	1.540	0.464	17	1.658	1.314	0.438	16
*Whaler sharks grouped	*Carcharhinus* spp.	Byproduct	63	3.349	3.020	0.756	47	2.548	1.310	0.328	20
Narrow sawfish	*Anoxypristis cuspidata*	TEPS	3	1.055	0.528	0.373	2	0.797	0.287	0.203	2
Dwarf Sawfish	*Pristis clavata*	TEPS	1	0.984			1	0.870			2
Green Sawfish	*Pristis zijsron*	TEPS	1	0.968			0				1
*Sawfish grouped	*A. cuspidate, P. clavata, P. zijsron*	TEPS	5	1.015	0.308	0.154	3	0.821	0.207	0.120	5
Winghead Shark	*Eusphyra blochii*	SoC	5	1.314	0.747	0.431	5	0.956	0.223	0.111	6
Whitespotted Eagle Ray	*Aetobatus ocellatus*	Bycatch	1	1.000			0				1
Bottlenose Wedgefish	*Rhynchobatus australiae*	Bycatch	1	0.952			0				1

Sharks (Undifferentiated)		Bycatch	2	0.984	0.023	0.016	1	0.870			2

(b)

			Control				Green LED				
Common Name	Scientific Name	Fishery Target	n	Mean CPUE	Sd	SE	n	Mean CPUE	Sd	SE	n. net pairs
Bony Fish											
Barramundi	*Lates calcarifer*	Target	17	2.284	1.493	0.668	28	7.369	4.748	2.741	5
King Threadfin	*Polydactylus macrochir*	Target	11	2.208	1.920	0.960	4	1.860	1.543	1.091	4
Blue Threadfin	*Eleutheronema tetradactylum*	Byproduct	23	3.131	2.487	1.112	20	2.135	1.064	0.402	7
Giant Queenfish	*Scomberoides commersonnianus*	Byproduct	3	2.118			0				1
Triple Tail	*Lobotes surinamensis*	Byproduct	1	0.714			0				1
Black Jewfish	*Protonibea diacanthus*	Bycatch	0				1	0.811			1
Elasmobranchs											
Common Blacktip Shark	*Carcharhinus limbatus*	Byproduct	1	0.984			0				1
Blacktip (Undifferentiated)	*C. limbatus, C. tilstoni.*	Byproduct	0				1	0.750			1
*Blacktip complex	*C. limbatus, C. tilstoni*	Byproduct	1	0.984			1	0.750			2
Graceful Shark	*Carcharhinus amblyrhynchoides*	Byproduct	9	1.439	1.293	0.647	12	3.370	0.593	0.419	5
Pigeye Shark	*Carcharhinus amboinensis*	Byproduct	5	0.910	0.270	0.135	10	2.129	0.446	0.258	5
Nervous Shark	*Carcharhinus cautus*	Byproduct	5	1.028	0.688	0.397	5	0.843	0.450	0.225	6
Whaler sharks (undifferentiated)	*Carcharhinus* sp.	Byproduct	2	0.583	0.032	0.023	2	0.984			3
*Whaler sharks grouped	*Carcharhinus* spp.	Byproduct	22	2.438	1.920	0.784	30	3.039	2.190	0.894	7
Lemon Shark	*Negaprion acutidens*	Byproduct	0				1	0.984			1
Dwarf Sawfish	*Pristis clavata*	TEPS	2	0.583	0.032	0.023	1	0.632			3
Green Sawfish	*P. zijsron*	TEPS	1	0.706			0				1
*Sawfish grouped	*P. clavata, P. zijsron*	TEPS	3	0.624	0.074	0.043	1	0.606			4
Winghead Shark	*Eusphyra blochii*	SoC	0				1	0.606			1
Sharks (Undifferentiated)		Bycatch	1	0.606			1	0.632			2

Green LEDs

Bony Fish

Overall trends

Catch for Aggregated Bony Fish differed significantly between Green LED nets compared to Control nets, with catches being 1.79 times (79%) higher in Green LED nets on average than in Control nets (GLMM: p = 0.008; Table 4(a), Figure 5). This indicates that Green LEDs may have an attractant effect for Bony Fishes, generally.

Species-specific trends

There was no significant difference in CPUE between Control and Green LED nets for any of bony fish species (paired t-tests: $p > 0.05$; Table 4(b)). However, there was a marginal difference for Blue Threadfin ($p = 0.077$), and a large effect size (Cohen's $d = -0.73$), suggesting a potential increase in catch rates associated with Green LEDs (Figure 5). For King Threadfin, although the difference was not significant, there was a moderate positive effect (Cohen's $d = 0.494$), indicating a slightly lower CPUE in Green LED nets (Figure 5). These trends indicate a likely attractant effect for Blue Threadfin and a potential deterrent effect for King Threadfin with Green LEDs that is worth investigating further for these inshore target species. Green LEDs did not appear to affect Barramundi CPUE.

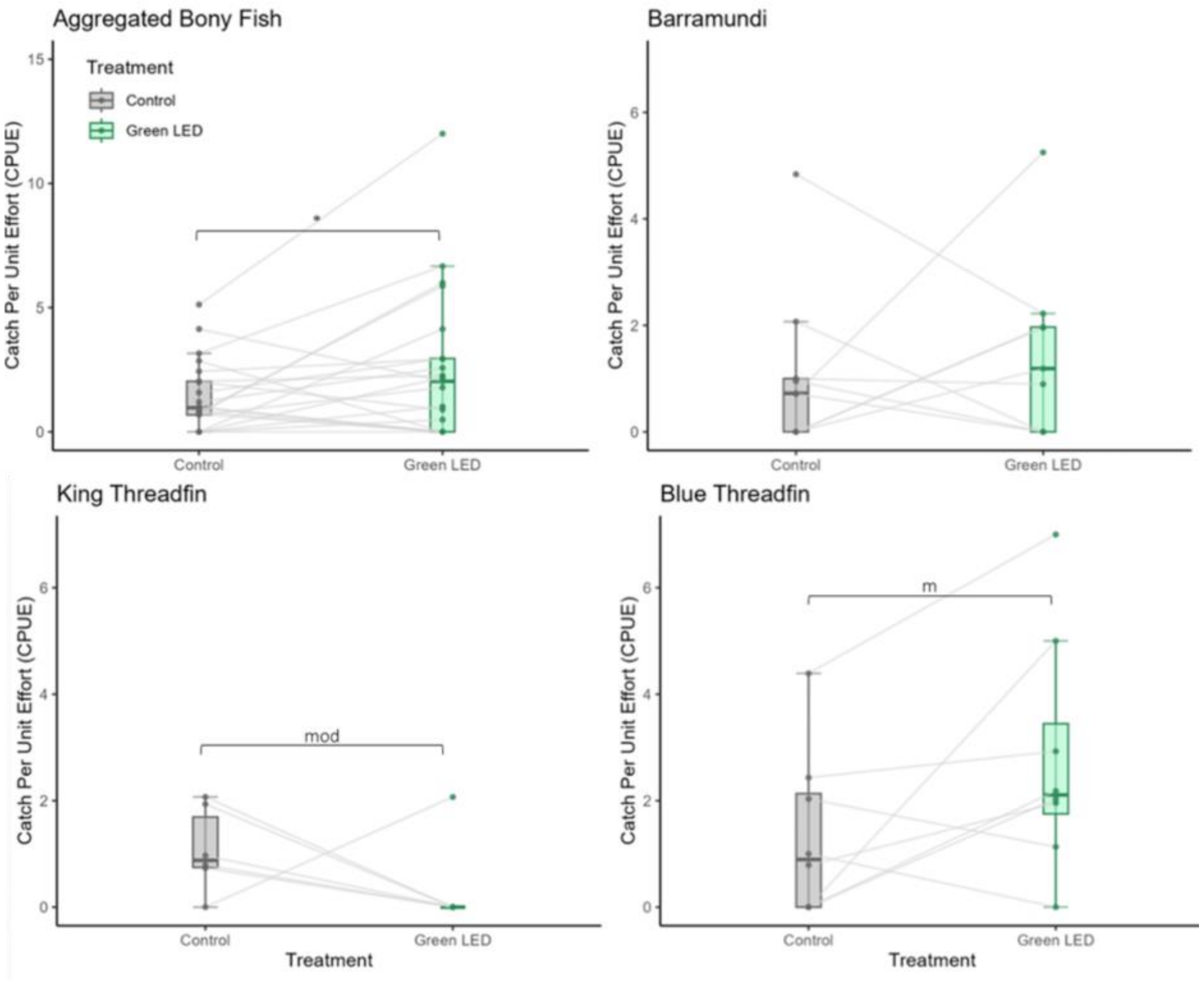


*Figure 5. Boxplots showing catch per unit effort (CPUE) for Aggregated Bony Fish, Barramundi, King Threadfin and Blue Threadfin caught during Green LED paired net deployments. Points indicate raw CPUE data for each net with grey lines connecting data from net pairs for each deployment. * = significant differences, m = marginally significant difference, mod = moderate effect.*

*Table 4. Table of summary statistics for comparisons between Control vs Green LED paired nets for Bony Fish. (a) Generalised Mixed Effects Model for Aggregated Bony Fish and (b) Paired T-Tests and effect size (Cohen's d) for species specific comparisons. N. trials in brackets in the total number of paired nets a species was caught in (including outliers) while the number not in brackets was the number of trials statistically assessed. * indicates a significant effect, ^{m} indicates marginal significance.*

(a)

	N. trials	Estimate	SE	Rate ratio	z-value	p-value
Aggregated Bony Fish						
Intercept		-1.029	0.268		-3.844	< 0.001*
Treatment (Green LED)	21	0.580	0.220	1.787	2.639	0.008*

(b)

Species or Group	N. trials	Paired T-Test					Effect size (Cohen's d)
		Mean difference	95% CI	t	df	p-value	
Barramundi	9	-0.354	-2.095 – 1.387	-0.468	8	0.652	-0.156
King Threadfin	6	0.737	-0.829 – 2.304	1.210	5	0.280	0.494
Blue Threadfin	8 (9)	-1.448	-3.100 – 0.204	-2.072	7	0.077^m	-0.733

Elasmobranchs

Overall trends

There was a marginal difference in catches for Aggregated Elasmobranchs between Green LED and Control nets, with catches being 1.28 times (28%) lower in Green LED nets than in Control nets (GLMM: p = 0.064; Table 5(a), Figure 6). This suggests a potential deterrent effect of Green LEDs on Elasmobranchs generally that is worth exploring further.

Species-specific trends

CPUE differed significantly between Control and Green LED nets for Graceful Sharks (p = 0.051; Table 5(b)), with higher CPUE in Green LED nets (Figure 6), and a strong effect (Cohen's d = -0.832), indicating that Green LEDs had an attractant effect for Graceful Sharks. Paired t-tests indicated no significant difference in CPUE between Control and Green LED nets for all other elasmobranch species/groups (p > 0.05; Table 5(b)). However, for Sawfish there was a moderate positive effect (Cohen's d = 0.418), indicating a trend towards lower CPUE in Green LED nets (Table 5(b), Figure 6). While not significant, given the conservation importance of this species, this trend warrants further investigation as a potential bycatch deterrent.

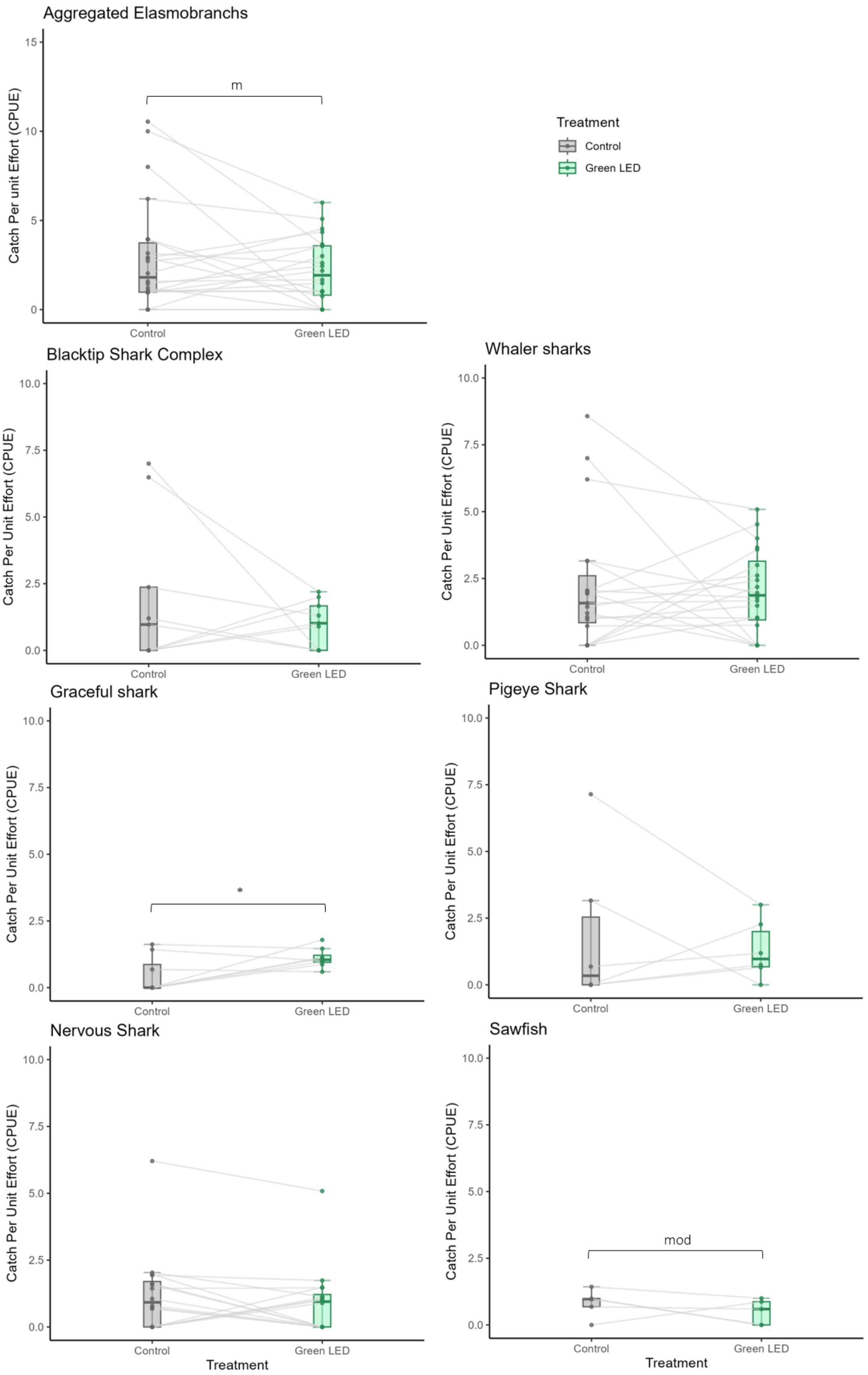


*Figure 6. Boxplots showing catch per unit effort (CPUE) for Aggregated Elasmobranchs, Blacktip Shark Complex, Whaler Sharks, Graceful Sharks, Pig Eye Sharks, Nervous Sharks, and Sawfish caught during Green LED paired net deployments. Points indicate raw CPUE data for each net with grey lines connecting data from net pairs for each deployment. Significant differences are denoted by *, marginally significant differences are denoted by m and moderate effects are denoted by mod.*

Table 5. Table of summary statistics for comparisons between Control vs Green LED paired nets for Elasmobranchs. (a) Generalised Mixed Effects Model for Aggregated Elasmobranchs and (b) Paired T-Tests and effect size (Cohen's d) for species specific comparisons.

(a)

	N. trials	Estimate	SE	Rate ratio	z-value	p-value
Aggregated Elasmobranchs						
Intercept		-0.142	0.193		-0.736	0.462
Treatment (Green LED)	22	-0.327	0.176	0.721	-1.854	0.064^{m}

(b)

Species or Group	N. trials	Paired T-Test					Effect size (Cohen's d)
		Mean difference	95% CI	t	df	p-value	
Elasmobranchs							
Blacktip Shark Complex	9	0.994	-1.291 – 3.278	1.003	8	0.345	0.334
Graceful Shark	8	-0.648	-1.299 - 0.003	-2.354	7	0.051*	-0.832
Pigeye Shark	6	0.521	-2.128 – 3.171	0.506	5	0.635	0.206
Nervous Shark	16	0.319	-0.272 - 0.910	1.152	15	0.268	0.288
Whaler Sharks	20	0.640	-0.729 - 2.0100	0.979	19	0.340	0.219
Elasmobranch TEPS							
Sawfish	5	0.320	-0.630 - 1.270	0.934	4	0.403	0.418

Electric Deterrents

Bony Fish

Overall trends

No significant difference was detected for Aggregated Bony Fish catches between Control and Electric Deterrent nets (paired t-test: p = 0.814; Table 7, Figure 7), suggesting no influence of the Electric Deterrent on Bony Fish generally.

Species-specific trends

Paired t-tests showed no significant difference in CPUE between Control and Electric Deterrent nets for any species (p > 0.05; Table 6). However, effect sizes for Barramundi and King Threadfin were moderate (Cohen's d = -0.546 and 0.440, respectively; Table 6) – for Barramundi this suggests there was a tendency for higher CPUE in the Electric Deterrent nets, while for King Threadfin this suggests a tendency for lower CPUE in the Electric Deterrent nets (Figure 7). This may translate to potential attraction and deterrent effect for these two target species, respectively, but sample sizes are low. In contrast, Electric Deterrents did not appear to affect Blue Threadfin CPUE.

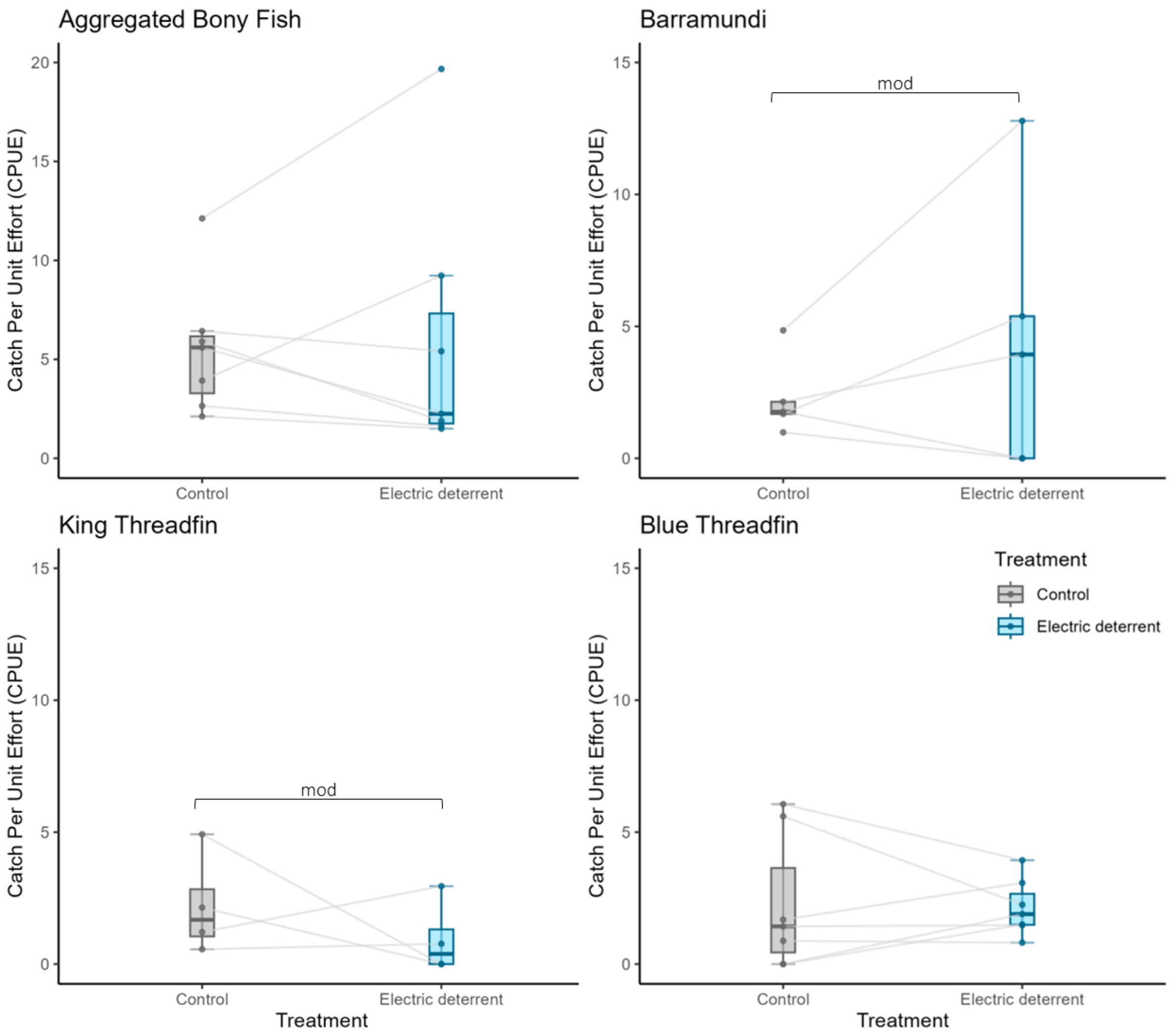


Figure 7. Boxplots showing catch per unit effort (CPUE) for Aggregated Bony Fish, Barramundi, King Threadfin and Blue Threadfin caught during Electric Deterrent paired net deployments. Points indicate raw CPUE data for each net with grey lines connecting data from net pairs for each deployment.

Table 6. Table of summary statistics for comparisons between Control vs Electric Deterrent paired nets for Bony Fish. (a) Paired T-Test for Aggregated Bony Fish and (b) Paired T-Tests and effect size (Cohen's d) for species specific comparisons.

(a)

	N. trials	Paired T-Test					Effect size (Cohen's d)
		Mean difference	95% CI	t	df	p-value	
Aggregated Bony Fish	7	-0.405	-4.433 - 3.622	-0.246	6	0.814	-0.093

(b)

Species or Group	N. trials	Paired T-Test					Effect size (Cohen's d)
		Mean difference	95% CI	t	df	p-value	
Target Bony Fish							
Barramundi	5	-2.137	-6.99 - 2.720	-1.222	4	0.289	-0.546
King Threadfin	4	1.278	-3.343 - 5.900	0.880	3	0.454	0.440
Blue Threadfin	7	0.102	-1.727 - 1.931	0.136	6	0.896	0.051

Elasmobranchs

Overall trends

No significant difference was detected for Aggregated Elasmobranch catches between Control and Electric Deterrent nets (Paired t-test: p = 0.798; Table 7, Figure 8), suggesting no influence of the Electric Deterrent on Elasmobranchs as a whole.

Species-specific trends

Blacktip Sharks were only caught in two paired nets and were therefore not analysed for differences in CPUE for Electric Deterrents. For all other elasmobranch species, paired t-tests indicated no significant difference in CPUE between Control and Electric Deterrent nets (p > 0.05; Table 7). However, for Sawfish the effect size was moderate and positive (Cohen’s d = 0.499; Table 7), suggesting a tendency for lower CPUE in Electric Deterrent nets, and therefore a potential deterrent effect. While sample sizes were low, in three of the four paired deployments where sawfish were caught, they were captured exclusively in the Control nets (Figure 8). These trends suggest further testing as a bycatch deterrent device for sawfish is warranted.

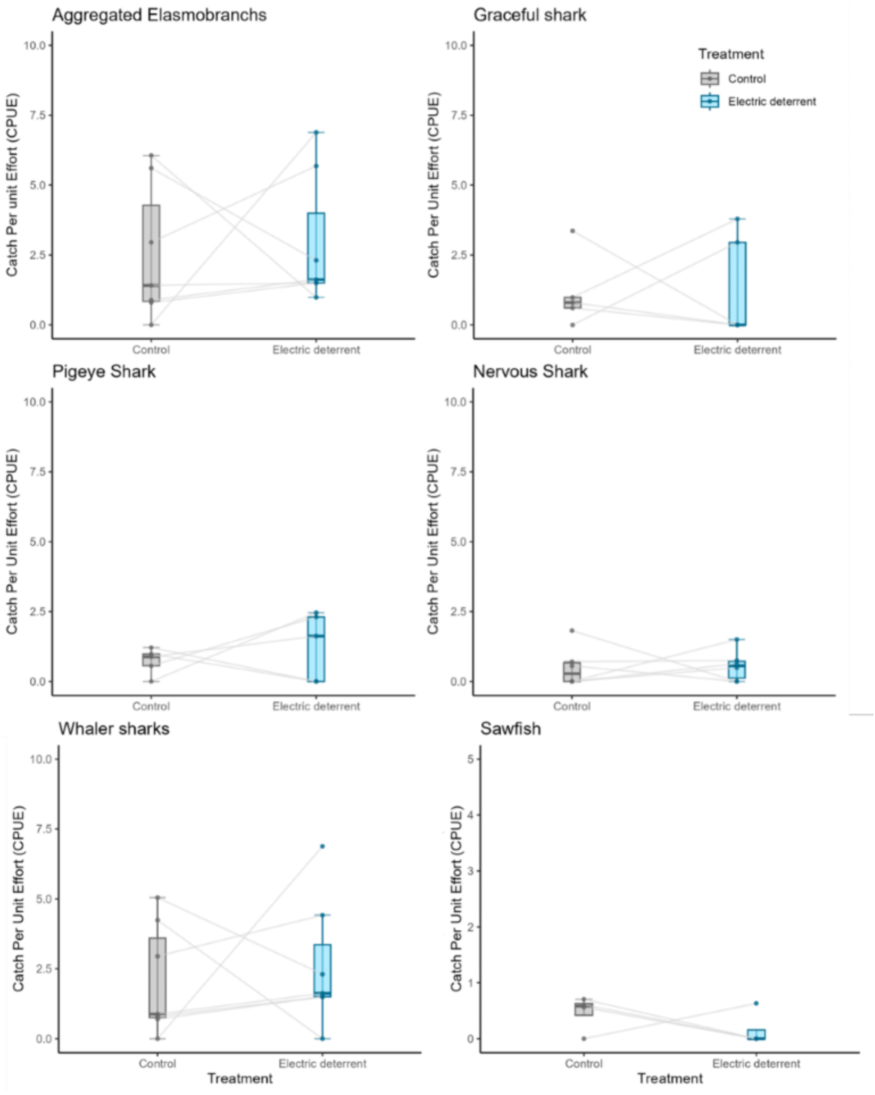


Figure 8. Boxplots showing catch per unit effort (CPUE) for Aggregated Elasmobranchs, Blacktip Shark Complex, Whaler Sharks, Graceful Sharks, Pigeye Sharks, Nervous Sharks, and Sawfish caught during Electric Deterrent paired net deployments. Points indicate raw CPUE data for each net with grey lines connecting data from net pairs for each deployment.

Table 7. Table of summary statistics for comparisons between Control vs Electric Deterrent paired nets for Bony Fish. (a) Paired T-Test for Aggregated Bony Fish and (b) Paired T-Tests and effect size (Cohen's d) for species specific comparisons.

(a)

	N. trials	Paired T-Test					Effect size (Cohen's d)
		Mean difference	95% CI	t	df	p-value	
Aggregated Elasmobranchs	7	-0.396	-4.007 - 3.216	-0.268	6	0.798	-0.101

(b)

Species or Group	N. trials	Paired T-Test					Effect size (Cohen's d)
		Mean difference	95% CI	t	df	p-value	
Elasmobranchs							
Graceful Shark	5	0.197	-3.524 - 3.130	-0.165	4	0.877	-0.074
Pigeye Shark	5	-0.550	-2.568 - 1.469	-0.756	4	0.492	-0.338
Nervous Shark	6	-0.048	-1.245 - 1.148	-0.103	5	0.923	-0.042
Whaler Sharks	7	-0.515	-3.783 - 2.752	-0.386	6	0.713	-0.146
Elasmobranch TEPS							
Sawfish	4	0.310	-0.694 - 1.314	0.984	3	0.398	0.4992

Conclusions

The Fishery-Independent Trials assessed the effects of Green LEDs and Electric Deterrents on gillnetting catch rates, with a focus on their impact on target species such as Barramundi and King Threadfin, as well as bycatch species including elasmobranchs and threatened species such as sawfish.

Green LEDs had a significant positive effect on Bony Fish CPUE overall, with catches being almost 80% higher in nets with Green LEDs compared with a control. This increase appeared to be driven by Blue Threadfin, a common byproduct in inshore Barramundi Fishing. With respect to target species, there was no effect on Barramundi, while King Threadfin showed a moderate decrease in CPUE, indicating that different target species may respond differently to Green LEDs. For elasmobranchs which are typically byproduct or bycatch for inshore Barramundi fishing, Green LEDs resulted in a marginal reduction in CPUE, overall. However, catches of Graceful Sharks were significantly higher in nets with Green LEDs suggesting an attractant effect. Meanwhile, no effect was observed for any other species, such as Blacktip Sharks, Pigeye Sharks or Nervous Sharks. Importantly, there was a moderate effect for Sawfish, with a trend towards lower catches in Green LED nets, suggesting that Green LEDs may help deter this threatened species but further sampling is required to confirm this trend.

For Electric Deterrents, there was a potential attractant effect for Barramundi and a potential deterrent effect for King Threadfin and Sawfish; however, these differences were not statistically significant. The results are therefore inconclusive, and further trials are necessary to confirm these trends.

Effects on fishery target species

Barramundi and King Threadfin are key target species for commercial inshore gillnet fishing in northern Australia, and were caught in good numbers during the trials. Analyses suggest that Green LEDs are unlikely to impact Barramundi catch rates, while Electric Deterrents may increase Barramundi catch rates, though further testing is needed to confirm the attractant potential for Electric Deterrents. In contrast, there was a potential trend towards reduced King Threadfin catches for both devices, suggesting a possible deterrent effect that may impact fishery operations targeting this species and warranting further testing. There was a strong trend for increased Blue Threadfin catches in Green LED nets, suggesting that Green LEDs may improve catch efficiency for this common byproduct species. Given the variability in target and byproduct species responses and the limited sample sizes, further trials are necessary to fully understand the potential effects of these deterrents on fishery operations and to ensure they do not unintentionally impact target catch efficiency.

Sharks are typically taken as byproduct species or discarded in inshore Barramundi fisheries, and the findings suggest that Green LEDs may lead to lower catches in elasmobranchs generally. Although, catches for Graceful Sharks were significantly increased in Green LED nets. In contrast, a number of whaler sharks (*Carcharhinus* spp.) are common target (i.e., Blacktip Shark Complex) or byproduct species in pelagic net fisheries operating further offshore (e.g., NT Offshore Net and Line Fishery, Qld Gulf of Carpentaria Finfish Fishery), and we found that for both Blacktip Sharks and Whaler Sharks (grouped), there was no detectable effect on catch rates for these species groups with either deterrent type. However, these trials were conducted in turbid, inshore environments more commonly associated with Barramundi fishing, and trials in offshore pelagic environments are needed to determine how these devices might influence catch rates in fisheries targeting these elasmobranch species.

Deterrence potential for TEPS

Sawfish are frequently caught in commercial gillnet fisheries in Northern Australia. During this study, three species (*Pristis prisis, P. zijsron,* and *Anoxypristis cuspidate*) were recorded in low numbers. Despite the limited sample sizes, analyses suggested that both Green LEDs and Electric Deterrents may reduce Sawfish catches. Therefore, further investigation into these bycatch reduction technologies for this highly threatened group is recommended.

Experimental limitations

Several limitations were faced during this study that should be considered when interpreting the results presented here. Catch composition was highly variable and replication was low, making species-specific comparisons difficult. This is particularly the case for threatened species, like Sawfish, where only low interactions were recorded. Additionally, there were few replicates for Electric Deterrents, reducing the statistical power of the analysis and the ability to detect differences in catch rates. While the results provide some insights into the potential effect (or lack thereof) on elasmobranchs which are targeted in some offshore pelagic net fisheries, the trials were conducted in inshore, turbid environments representative of commercial Barramundi fishing, and the results may not be directly applicable to pelagic net fisheries that operate in clearer, offshore waters.

Industry implications

While Green LEDs and Electric Deterrents showed some promise as bycatch reduction tools for Sawfish, albeit with low replication, the effects on target species were variable. Based on the results presented here, fishers targeting Barramundi are unlikely to experience catch reductions with Green LEDs but may see reduced catches of King Threadfin. Conversely, potential increases in Blue Threadfin catches could alter species compositions in landings. Although the potential to reduce Sawfish bycatch is encouraging, the current evidence is insufficient to support broad implementation. Further research is needed to confirm effectiveness across different fisheries, conditions, and species compositions, and to better understand potential trade-offs between bycatch reduction and any unintended impacts on target species. For pelagic net fisheries, further trials in offshore environments are needed before conclusions can be drawn.

Recommendations and Future Research

The findings of this study highlight the need for further research to refine the application of Green LEDs and Electric Deterrents as bycatch mitigation technologies in gillnet fisheries. While some promising trends were observed, particularly for Sawfish, the strength of conclusions is limited by small sample sizes and variability in catch compositions. To advance the development and application of these technologies, future research should focus on the following priorities:

- **Expanded Sampling and Replication**: Additional trials with increased sample sizes are essential to improve statistical power and better assess species-specific responses to deterrents. Greater replication will help address variability in catch compositions and strengthen conclusions regarding deterrent efficacy.
- **Species-Specific Responses**: Given the mixed effects observed across target, byproduct, and TEPS species, further research is needed to optimise the deterrent technologies for different species. In particular, studies should explore whether modifications to deterrent intensity, duration, or configuration in deployment can improve their ability to minimise bycatch while maintaining target catches.
- **Trials in Offshore and Clear-Water Environments**: The present study was conducted in inshore, turbid environments representative of commercial Barramundi fisheries. To determine broader applicability, trials should be conducted in offshore, pelagic environments where fisheries targeting Whaler Sharks and other pelagic species using pelagic nets operate. This will help evaluate whether deterrents function effectively under different environmental conditions.

By addressing these research priorities, future studies can provide stronger evidence for the effectiveness and operational feasibility of visual and electric deterrents in reducing bycatch while maintaining catch efficiency for target species. This will support informed decision-making regarding their potential integration into commercial gillnet fisheries.

Fishery-Dependent Trials

The Fishery-Dependent trials aimed to test the selected bycatch mitigation devices under normal commercial net fishing operations. The trials were intended to provide insights into the real-world applicability and effectiveness of the Green LED and Electric Deterrent devices, and insights into their deployment under typical commercial fishing conditions. As for the fishery-independent trials, a successful mitigation measure was expected to show a significant reduction in catches of non-target species, including TEPS, while maintaining catch levels for target species.

This project intended to conduct Fishery-Dependent Trials in both the NT Barramundi Fishery (using gillnets) and the NT Offshore Net and Line Fishery (NT ONLF) (using pelagic nets). Due to changes to the NT Barramundi Fishery announced in late 2024, including a phase out of gillnets in the fishery, we were unable to conduct trials within this fishery and trials were only conducted in the NT ONLF.

Methods

Study location

The Fishery Dependent Trials were conducted onboard a commercial fishing vessel operating in the NT ONLF in fishing grounds west of Darwin, NT between 16 to 23 March 2025 (Figure 9). The NT ONLF operates from the two nautical miles from the low water mark to the boundary of the Australian Fishing Zone. The NT ONLF is a quota-managed fishery targeting Grey Mackerel (*Scomberomorus semifasciatus*), Blacktip Sharks (*Carcharhinus limbatus and C. tilstoni*), and Spot-tail sharks (*C. sorrah*). Numerous other bony fish and elasmobranchs are taken as byproducts. Key TEPS include sawfish and devil rays (*Mobula* spp.), as well as dolphins and turtles. Operators use pelagic nets up to 200m long, with a mesh size of 160-185 mm and drop of 50 to 100 meshes, which are used to fish the surface waters.

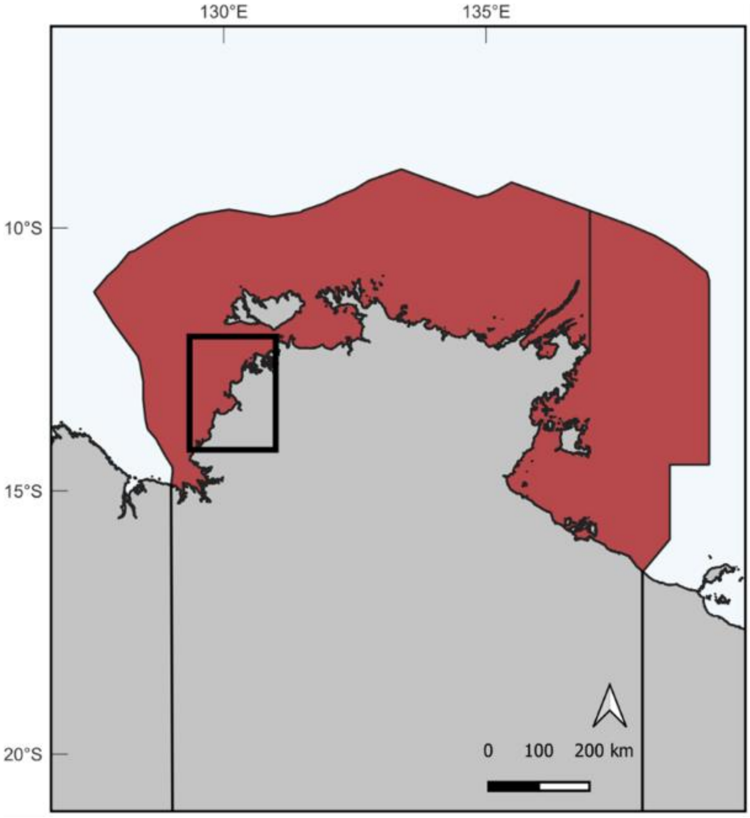


Figure 9. Map of the study location for the Fishery-Dependent Trials in the NT Offshore Net and Line Fishery (red shaded area). Black bounding box indicates area of fishing activity.

Experimental Design

Trials involved the deployment of a 990 m pelagic net (165 mm mesh, 8 m deep) that was divided into four panels: 225 m monofilament, 120 m twine, 150 m monofilament, and 495 m twine (Figure 10). Monofilament nets were made from clear monofilament strands, while the twine nets used a green multi-fibre twine. To simplify deployment of devices by crews, devices were deployed in two treatment sections, which spanned approximately halfway across a panel of Monofilament net and a Twine net, with the other half of each net serving as the Control section for the respective net type (Figure 10). Devices were tethered to 15cm shark clips using rope (Green LEDs) or 200lb monofilament (Electric Deterrents), and were attached along the floatline of the net in treatment sections, with one device attached to a float and one device attached directly to the floatline between every float which were spaced every ~15m, resulting in a spacing of ~7.5m between devices. To reduce potential bias, the Green LEDs and Electric Deterrents were alternated between the two treatment sections with each deployment.

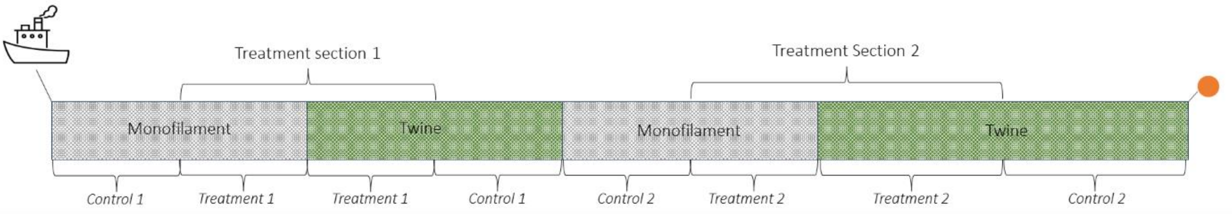


Figure 10. Schematic of Fishery Dependent trial design.

Nets were shot and retrieved using a mechanical winch with the net coiled on a drum. When being shot, the crew affixed devices to the net per the design. Nets were left to soak for two to three hours before being retrieved. On retrieval, devices were removed and all animals caught were identified at the species level. Fishing occurred at night, with up to 3 shots conducted per night, as per typical operations.

Statistical Analysis

For all statistical analyses, catches were compared within Treatment Sections (Control vs Green LED or Electric Deterrent) for each of the two Net Types (Monofilament or Twine). A unique Set ID was assigned to each Treatment Section pairing within each Net Type (i.e., Monofilament net Control and Green LED, Monofilament Control and Electric Deterrent, Twine Control and Green LED, Twine Control and Electric Deterrent). All analyses were conducted in R (version 4.3.3).

Overall trends for bony fishes and elasmobranchs

To investigate overall trends in catches for bony fishes and elasmobranchs, linear mixed models (LMMs) were used to compare the effects of Net Type (Monofilament or Twine), Treatment Section (Control and Green LED or Electric Deterrent) and the interaction between the two on catch rates for each of these groups. Four separate models were run: bony fishes for Green LED pairs, bony fishes for Electric Deterrent pairs, elasmobranchs for Green LED pairs, elasmobranchs for Electric Deterrent pairs). Aggregated catches consisted of all bony fish and all elasmobranchs caught for the respective Treatment Section in each Set ID. The catch data were modelled as catch per unit effort (CPUE), calculated as the number of animals caught divided by 100-meter-hours (100mh; net length (in meters)/100m x soak time in hours). This provided a standardised measure of catch that takes into account variation in net lengths and soak times. The models were fit using the *lme4* package and were specified as follows:

$$\log(CPUE+1) \sim Treatment * Net\ Type + (1|Set\ ID)$$

where, *Treatment* refers to the Treatment Section being tested (Control or Green LED, or Control or Electric Deterrent), *Net Type* refers to the type of net being compared (Monofilament or Twine), and *Set ID* is the unique identifier for each net pairing, included as a random factor to account for the paired nature of the data. CPUE was log-transformed as log(CPUE + 1) to satisfy normality assumptions of the models. Model diagnostics, including residual plots, normality tests, and variance checks, were conducted to assess the fit of the models. Conditional and Marginal R^2 was calculated for each model to quantify the proportion of variance in CPUE explained by the full model and just the fixed effects (excluding Set ID), and determine variability between Set IDs. Post-hoc pairwise comparisons were then performed using estimated marginal means (*emmeans*) to identify specific treatment effects and determine where statistically significant differences occurred.

Species-specific trends in catches

To investigate whether there were any species-specific responses, species caught most frequently across net pairs and species of commercial and conservation interest were selected for statistical analysis. This included Grey Mackerel (fishery target), Blacktip Shark Complex (fishery target), Spot-tail Sharks (fishery target), and Hammerhead Sharks Grouped (byproduct, and species of conservation interest). Unfortunately, only one TEPS was caught, which precluded a meaningful assessment of the effectiveness of the devices on TEPS during this study.

As with the overall catch analysis, species-specific trends were investigated using CPUE and LMMs with the same data and model specifications. However, for Hammerhead Sharks, the sample size was too small to support the use of an LMM. Therefore, paired t-tests were conducted to assess differences in CPUE between treatments for this species group, with separate paired t-tests for Monofilament net sets and Twine net sets.

Results

A total of 19 shots were conducted, resulting in 19 replicates for each Treatment across each Net Type. One replicate for the Electric Deterrent in the Monofilament net was removed due to the net becoming heavily twisted and not fishing effectively.

Catch composition was relatively consistent across Set IDs (shots) (Table 8). Among Bony Fish, Grey Mackerel dominated catches, while for Elasmobranchs Blacktip Sharks and Spot-tail Sharks were caught most frequently (Table 8). Hammerhead Sharks (Scalloped Hammerheads, Great Hammerheads, and Winghead sharks) were caught in moderate numbers, while only one TEPS was caught – a Long Horned Pygmy Devil Ray (Table 8).

*Table 8. Mean and standard error (SE) catch per unit effort (CPUE) for all species caught during the Fishery-dependent Trials for (a & b) Green LED paired net deployments and (c and d) electric deterrent paired net deployments, in monofilament (a & c) and twine (b & d) nets. TEPS = Threatened, Endangered and Protected Species. SoCI = Species of Conservation Interest. n = number of individual animals. * = grouped species.*

(a) Green LED - Monofilament (n = 19)

			Control				Green LED				
Common Name	Scientific Name	Fishery Target	n	Mean CPUE	Sd	SE	n	Mean CPUE	Sd	SE	n. net pairs
Bony Fish			**56**	**2.114**	**1.705**	**0.473**	**62**	**2.291**	**2.495**	**0.692**	**16**
Grey Mackerel	*Scomberomorus semifasciatus*	Target	47	2.106	1.391	0.419	57	2.496	2.605	0.785	14
Spanish Mackerel	*Scomberomorus commerson*	Byproduct	1	0.443	0	0	0				1
Spotted Mackerel	*Scomberomorus munroi*	Byproduct	3	1.681	0	0	2	0.458	0.010	0.007	2
Mackerel (Undifferentiated)	*Scomberomorus* sp.	Byproduct	0				1	0.606			1
Blue Threadfin	*Eleutheronema tetradactylum*	Byproduct	0				1	0.402	0	0	1
Golden Trevally	*Gnathanodon speciosus*	Byproduct	1	0.642	0	0	0				1
Mackerel Tuna	*Euthynnus affinis*	Byproduct	2	0.737	0	0	0				1
Pomfret	*Parastromateus niger*	Bycatch	0				1	0.402			1
Pacific Sailfish	*Istiophorus platypterus*	Bycatch	1	0.449	0	0	0				1
Remora	*Echeneis naucrates*	Bycatch	1	0.369	0	0	0				1
Elasmobranchs			**53**	**1.784**	**1.625**	**0.420**	**60**	**1.999**	**1.339**	**0.371**	**16**
Common Blacktip Shark	*Carcharhinus limbatus*	Target	18	1.213	0.906	0.319	18	0.994	0.297	0.105	10
Australian Blacktip Shark	*Carcharhinus tilstoni*	Target	9	0.923	0.540	0.242	10	0.585	0.267	0.101	9
*Blacktip Shark Complex	*C. limbatus, C. tilstoni*	Target	27	1.591	1.434	0.478	28	1.338	0.538	0.179	11
Spot-tail Shark	*Carcharhinus sorrah*	Target	6	0.594	0.159	0.071	11	0.668	0.215	0.081	10
Blacktip Reef Shark	*Carcharhinus melanopterus*	Byproduct	1	0.541	0	0	0				1
Grey Reef Shark	*Carcharhinus amblyrhynchos*	Byproduct	2	0.737	0	0	0				1
Graceful Shark	*Carcharhinus amblyrhynchoides*	Byproduct	1	0.443	0	0	0				1
Nervous Shark	*Carcharhinus cautus*	Byproduct	1	0.428	0	0	0				1
Whitecheek Shark	*Carcharhinus dussumieri*	Byproduct	0				1	0.463	0	0	1
Whaler shark (Undifferentiated)	*Carcharhinus* sp.	Byproduct	0				1	0.510	0	0	1
Tawny Nurse Shark	*Nebrius ferrugineus*	Byproduct	1	0.539	0	0	1	0.357	0	0	2
Milk shark	*Rhizoprionodon acutus*	Bycatch	9	0.884	0.607	0.271	11	0.713	0.287	0.108	9
Great Hammerhead	*Sphyrna mokarran*	SoCI	1	0.541	0	0	0				1
Scalloped Hammerhead	*Sphyrna lewini*	SoCI	2	0.856	0	0	3	0.669	0.291	0.206	3
Winghead Shark	*Eusphyra blochii*	SoCI	2	0.484	0.108	0.076	3	0.572	0.201	0.142	4
*Hammerheads Grouped	Sphyrnidae	SoCI	5	0.591	0.189	0.094	7	0.736	0.223	0.112	8

(b) Green LED – Twine (n = 19)

			Control				Green LED				
Common Name	Scientific Name	Fishery Target	n	Mean CPUE	Sd	SE	n	Mean CPUE	Sd	SE	n. net pairs
Bony Fish			**70**	**1.508**	**1.547**	**0.429**	**44**	**1.069**	**0.939**	**0.297**	**14**
Grey Mackerel	*Scomberomorus semifasciatus*	Target	60	1.442	1.343	0.388	43	1.059	0.938	0.297	13
Spotted Mackerel	*Scomberomorus munroi*	Byproduct	3	0.496	0.412	0.292	0				2
Golden Snapper	*Lutjanus johnii*	Byproduct	2	0.349	0.359	0.254	0				2
Mackerel Tuna	*Euthynnus affinis*	Byproduct	2	0.197			0				1
Longtail Tuna	*Thunnus tonggol*	Byproduct	2	0.130	0.007	0.005	0				2
Trevally species	*Carangidae* sp.	Byproduct	1	0.153			0				1
Pomfret	Parastromateus niger	Bycatch	0				1	0.100			1
Elasmobranchs			**62**	**1.039**	**0.686**	**0.198**	**44**	**0.716**	**0.463**	**0.140**	**15**
Common Blacktip Shark	*Carcharhinus limbatus*	Target	12	0.516	0.643	0.239	13	0.434	0.375	0.142	10
Australian Blacktip Shark	*Carcharhinus tilstoni*	Target	12	0.407	0.268	0.109	7	0.280	0.335	0.137	9
* Blacktip Shark Complex	*C. limbatus, C. tilstoni*	Target	24	0.673	0.510	0.170	20	0.524	0.354	0.118	13
Spot-tail Shark	*Carcharhinus sorrah*	Target	23	0.462	0.232	0.082	9	0.263	0.095	0.047	8
Blacktip Reef Shark	*Carcharhinus melanopterus*	Byproduct	4	0.380			1	0.100			2
Grey Reef Shark	*Carcharhinus amblyrhynchos*	Byproduct	1	0.120			0				1
Creek Whaler	*Carcharhinus fitzroyensis*	Byproduct	0				6	0.601			1
Tawny Nurse Shark	*Nebrius ferrugineus*	Byproduct	2	0.443	0.487	0.344	0				2
Milk shark	*Rhizoprionodon acutus*	Bycatch	2	0.369	0.330	0.234	1	0.637			2
Great Hammerhead	*Sphyrna mokarran*	SoCI	4	0.199	0.122	0.086	3	0.115	0.022	0.013	4
Scalloped Hammerhead	*Sphyrna lewini*	SoCI	2	0.099	0.005	0.003	3	0.159	0.058	0.041	3
Winghead Shark	*Eusphyra blochii*	SoCI	0				1	0.106			1
*Hammerheads Grouped	Sphyrnidae	SoCI	6	0.198	0.158	0.091	7	0.192	0.082	0.041	4

(c) Electric Deterrent – Monofilament (n = 18)

			Control				Electric Deterrent				
Common Name	Scientific Name	Fishery Target	n	Mean CPUE	Sd	SE	n	Mean CPUE	Sd	SE	n. net pairs
Bony Fish			**54**	**2.123**	**1.776**	**0.493**	**65**	**1.892**	**1.784**	**0.461**	**18**
Grey Mackerel	*Scomberomorus semifasciatus*	Target	47	1.992	1.475	0.426	59	1.870	1.804	0.482	17
Spanish Mackerel	*Scomberomorus commerson*	Byproduct	2	0.510	0.117	0.082	0				2
Spotted Mackerel	*Scomberomorus munroi*	Byproduct	2	1.185			1	0.424			2
Mackerel (Undifferentiated)	*Scomberomorus* sp.	Byproduct	1	0.593			1	0.424			2
Blue Threadfin	*Eleutheronema tetradactylum*	Byproduct	1	0.417			2	0.645			1
Golden Snapper	*Lutjanus johnii*	Byproduct	0				1	0.321			1
Pomfret	Parastromateus niger	Bycatch	1	0.482			1	0.379			2
Elasmobranchs			**48**	**2.145**	**2.610**	**0.787**	**71**	**1.950**	**1.755**	**0.439**	**16**
Common Blacktip Shark	*Carcharhinus limbatus*	Target	23	3.690	3.430	1.980	24	1.251	1.041	0.368	9
Australian Blacktip Shark	*Carcharhinus tilstoni*	Target	7	0.915	0.450	0.225	12	0.685	0.479	0.169	8
* Blacktip Shark Complex	*C. limbatus, C. tilstoni*	Target	30	2.455	2.551	1.042	36	1.408	1.367	0.412	11
Spot-tail Shark	*Carcharhinus sorrah*	Target	6	0.635	0.201	0.100	16	0.872	0.418	0.148	10
Graceful Shark	*Carcharhinus amblyrhynchoides*	Byproduct	1	0.501			0				1
Pigeye Shark	*Carcharhinus amboinensis*	Byproduct	0				1	0.255			1
Whaler shark (Undifferentiated)	*Carcharhinus* sp.	Byproduct	1	0.580			0				1
Tawny Nurse Shark	*Nebrius ferrugineus*	Byproduct	0				2	0.477			1
Milk shark	*Rhizoprionodon acutus*	Bycatch	6	1.045	0.532	0.307	11	1.018	0.573	0.256	6
Great Hammerhead	*Sphyrna mokarran*	SoCI	1	0.571			1	0.323			2
Scalloped Hammerhead	*Sphyrna lewini*	SoCI	1	0.436			0				1
Winghead Shark	*Eusphyra blochii*	SoCI	2	0.550	0.173	0.122	3	0.791	0.663	0.469	3
*Hammerheads Grouped	Sphyrnidae	SoCI	4	0.527	0.117	0.059	4	0.953	0.435	0.307	5
Longhorned Pygmy Devilray	*Mobula eregoodoo*	TEPS	0				1	0.530			1

(d) Electric Deterrent – Twine (n = 19)

			Control				Electric Deterrent				
Common Name	Scientific Name	Fishery Target	n	Mean CPUE	Sd	SE	n	Mean CPUE	Sd	SE	n. net pairs
Bony Fish			**183**	**1.767**	**3.419**	**0.855**	**228**	**2.469**	**3.641**	**0.940**	**18**
Grey Mackerel	*Scomberomorus semifasciatus*	Target	182	1.761	3.421	0.855	220	2.359	3.602	0.930	18
Spanish Mackerel	*Scomberomorus commerson*	Byproduct	0				2	0.205			1
Spotted Mackerel	*Scomberomorus munroi*	Byproduct	0				2	0.121	0.031	0.022	2
Mackerel (Undifferentiated)	*Scomberomorus* sp.	Byproduct	1	0.094			1	0.126			2
Golden Snapper	*Lutjanus johnii*	Byproduct	0				1	0.126			1
Longtail Tuna	*Thunnus tonggol*	Byproduct	0				1	0.099			1
Tarpon	*Megalops cyprinoides*	Byproduct	0				1	0.855			1
Elasmobranchs			**86**	**1.357**	**0.901**	**0.272**	**60**	**1.291**	**1.213**	**0.324**	**15**
Common Blacktip Shark	*Carcharhinus limbatus*	Target	25	0.533	0.252	0.089	16	0.786	0.765	0.289	10
Australian Blacktip Shark	*Carcharhinus tilstoni*	Target	14	0.437	0.342	0.140	11	0.661	0.454	0.185	7
* Blacktip Shark Complex	*C. limbatus, C. tilstoni*	Target	39	0.766	0.459	0.153	27	1.183	1.098	0.388	10
Spot-tail Shark	*Carcharhinus sorrah*	Target	16	0.423	0.224	0.085	12	0.448	0.611	0.216	9
Blacktip Reef Shark	*Carcharhinus melanopterus*	Byproduct	1	0.114	0.160	0.114	3	0.382	0.160	0.113	3
Graceful Shark	*Carcharhinus amblyrhynchoides*	Byproduct	2	0.189			0				1
Nervous Shark	*Carcharhinus cautus*	Byproduct	0				1	0.157			1
Whitecheek Shark	*Carcharhinus dussumieri*	Byproduct	2	0.126	0.005	0.003	0				2
Creek Whaler		Byproduct	1	0.568			0				1
Tawny Nurse Shark	*Nebrius ferrugineus*	Byproduct	1	0.114			0				1
Milk shark	*Rhizoprionodon acutus*	Bycatch	8	0.502	0.155	0.090	7	0.561	0.669	0.299	7
Great Hammerhead	*Sphyrna mokarran*	SoCI	7	0.316	0.204	0.102	2	0.114	0.017	0.012	5
Scalloped Hammerhead	*Sphyrna lewini*	SoCI	4	0.214	0.098	0.069	3	0.131	0.027	0.016	3
Winghead Shark	*Eusphyra blochii*	SoCI	5	0.159	0.088	0.044	5	0.168	0.071	0.036	4
*Hammerheads Grouped	Sphyrnidae	SoCI	16	0.388	0.213	0.087	10	0.259	0.120	0.053	7

Green LEDs

Bony Fish

There was no significant difference in CPUE between the Treatments (Control vs. Green LED), Net Type (Monofilament vs. Twine), or the interaction for Aggregated Bony Fish or for Grey Mackerel ($p > 0.05$; Figure 11, Table 9). Grey Mackerel made up the vast majority of bony fish catches, and therefore differences in the models were negligible. The results suggests that Green LEDs had no discernible effect on catches of Bony Fish overall or for Grey Mackerel. However, variation between sets was very high (Table 9), and increased sampling is likely required to confirm the lack of an effect.

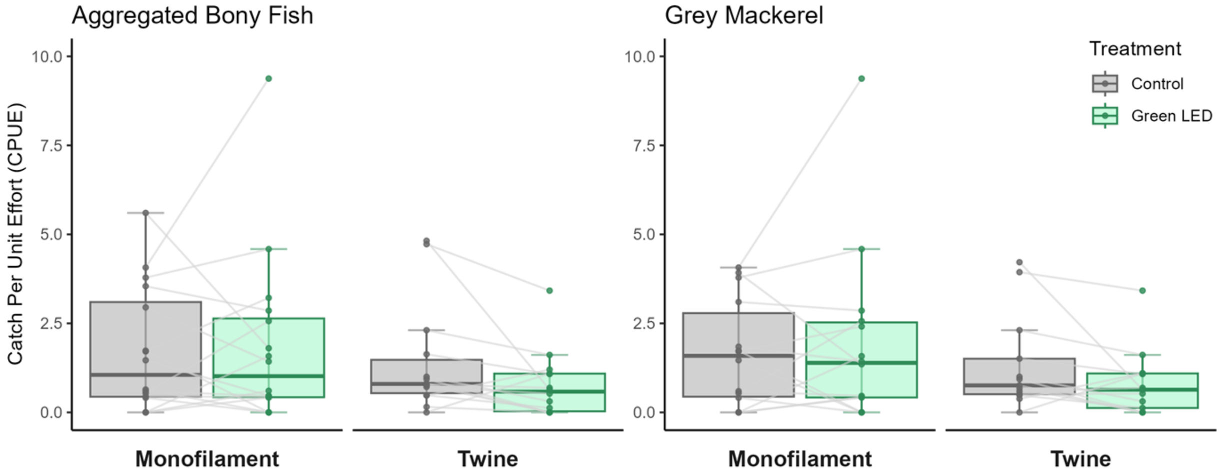


Figure 11. Boxplots showing catch per unit effort (CPUE) for Aggregated Bony Fish and Grey Mackerel caught during Green LED net deployments for the Fishery Dependent Trials in Monofilament and Twine nets. Points indicate raw CPUE data for each net with grey lines connecting data from net pairs (control and Green LED) for each deployment.

*Table 9. Table of summary statistics for comparisons between Control vs Green LED paired nets in Monofilament and Twine nets for Aggregated Bony Fish and Grey Mackerel. (a) Linear Mixed Effects Model results and (b) Estimated Marginal Mean Post-Hoc contrasts. NB: estimated marginal means are on the log(CPUE+1) transformed scale. * indicates a significant effect, ^{m} indicates a marginal effect.*

(a) LMM results

Aggregated Bony Fish	Estimate	SE	df	t-value	p-value
Intercept	0.811	0.146	42.3	5.541	<0.001*
Treatment (Green LED)	-0.003	0.136	28	-0.023	0.982
Net Type (Twine)	-0.081	0.214	42.3	-0.376	0.709
Treatment (Green LED) * Net Type (Twine)	-0.261	0.199	28	-1.313	0.200
Conditional $R^2 = 0.593$, Marginal $R^2 = 0.053$					

Grey Mackerel	Estimate	SE	df	t-value	p-value
Intercept	0.813	0.153	39.1	5.303	<0.001*
Treatment (Green LED)	0.021	0.149	25	0.144	0.887
Net Type (Twine)	-0.091	0.221	39.1	-0.411	0.683
Treatment (Green LED) * Net Type (Twine)	-0.245	0.215	25	-1.141	0.265
Conditional $R^2 = 0.553$, Marginal $R^2 = 0.051$					

(b) Contrasts

Aggregated Bony Fish	Estimate	SE	df	t-ratio	p-value
Monofilament	0.003	0.136	28	0.023	0.982
Twine	0.264	0.145	28	1.819	0.080

Grey Mackerel	Estimate	SE	df	t-ratio	p-value
Monofilament	-0.021	0.149	25	-0.144	0.887
Twine	0.223	0.154	25	1.446	0.161

Elasmobranchs

There was no significant difference in CPUE between Treatment (Control vs. Green LED), Net Type (Monofilament vs. Twine) or the interaction for Aggregated Elasmobranchs (LMM: $p > 0.05$; Table 10a). However, there was a marginal difference by Net Type ($p = 0.077$), suggesting overall lower CPUE (~27%) in Twine nets (Figure 12, Table 10a). This was driven by Blacktip Shark Complex CPUE, with the relevant model showing significantly lower CPUE in Twine nets (LMM: $p = 0.028$, ~43% lower; Table 10a), but no effect of the deterrent devices. For Spot-tail Sharks, there was a significant interaction between Treatment and Net Type (LMM: $p = 0.015$; Table 10a), with post-hoc comparisons indicating significantly lower CPUE in Twine nets with Green LEDs compared to Control, by approximately 21% ($p = 0.034$; Table 10b). No significant difference in CPUE was found for the Hammerhead Shark Group in either Monofilament or Twine nets (paired t-tests: $p > 0.05$; Table 10c). However, a moderate negative effect (Cohen's $d = -0.434$) was observed in Twine nets, suggesting a possible attractant effect of Green LEDs (Figure 12).

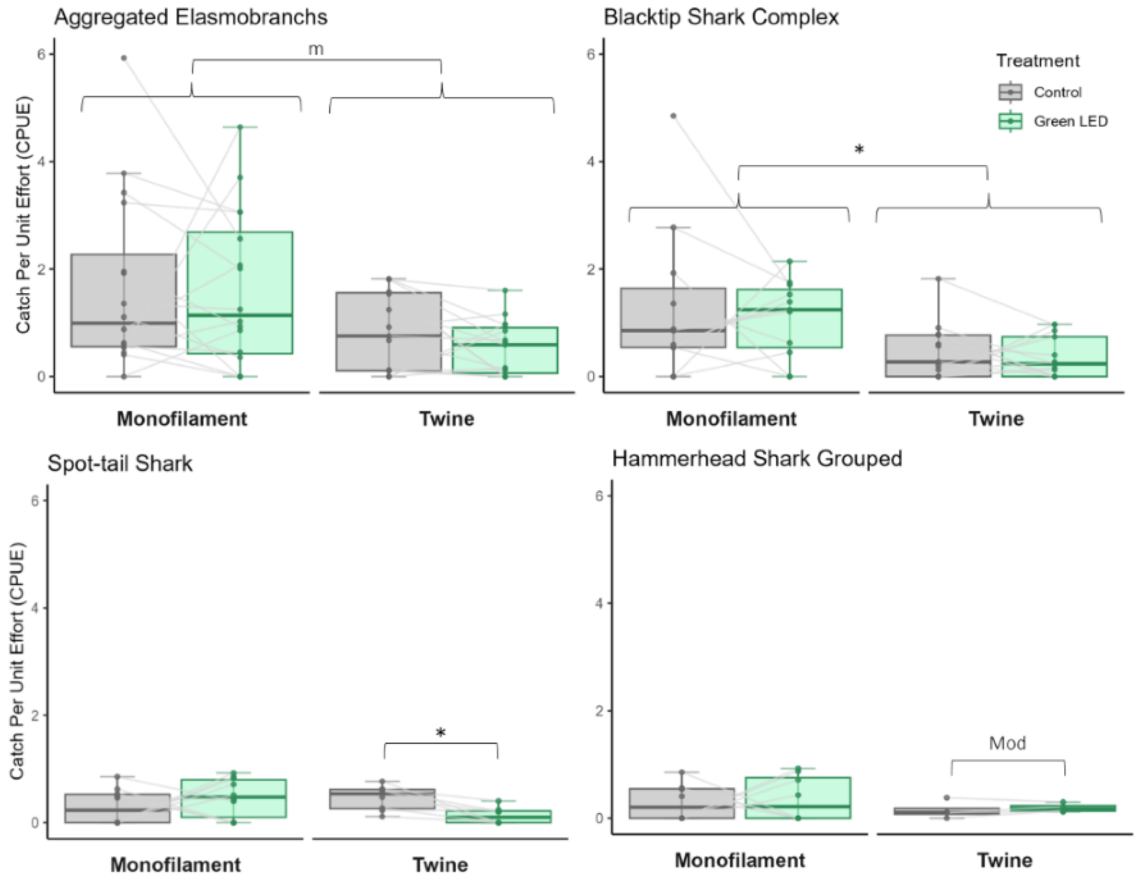


*Figure 12. Boxplots showing catch per unit effort (CPUE) for Aggregated Elasmobranchs, Blacktip Shark Complex, Spot-tail Sharks, and Hammerhead Sharks Grouped caught during Green LED net deployments for the Fishery Dependent Trials in Monofilament and Twine nets. Points indicate raw CPUE data for each net with grey lines connecting data from net pairs (control and Green LED) for each deployment. * = significant differences, m = marginally significant difference, mod = moderate effect (Hammerhead Sharks only).*

The Aggregated Elasmobranch model explained a moderate proportion of variation in CPUE (Conditional $R^2 = 0.414$), but the Marginal R^2 was low (0.144), indicating that most of the variation was attributable to between-set differences (Set ID), not the fixed effects of Treatment or Net Type (Table 10). The models for the Blacktip Shark Complex and Spot-tail Sharks explained less total variation (Conditional $R^2 = 0.231$ and 0.175, respectively), but had slightly higher Marginal R^2 values for the fixed effects (0.197 and 0.175; Table 10), suggesting more of the observed variance in CPUE was associated with Treatment and Net Type in these groups.

Overall, these results suggest that Green LEDs may reduce Spot-tail Shark catches in Twine nets. No clear effects of treatment were detected for the Blacktip Shark Complex or Aggregated Elasmobranchs overall, but Blacktip Shark catches were significantly reduced in Twine nets overall. For Hammerhead Sharks, Green LEDs in twine nets may increase catches, but this effect was not statistically significant. Importantly, inter-set variability explained a large proportion of the variance across all models, indicating that unmeasured environmental or operational factors may substantially influence catch rates. Further sampling across a wider range conditions would help clarify these trends.

*Table 10. Table of summary statistics for comparisons between Control vs Green LED paired nets in Monofilament and Twine nets for Aggregated Bony Fish. (a) Linear Mixed Effects Model results and (b) Estimated Marginal Mean Post-Hoc contrasts. NB: both the LMM and estimated marginal mean contrasts are on the log(CPUE+1) transformed scale. (c) Table of summary statistics for paired t-test for Hammerhead Sharks Grouped between Control vs Green LEDs for separate tests for each Net Type (Monofilament and Twine). * indicates a significant effect, m indicates a marginal effect.*

(a)

Aggregated Elasmobranchs	Estimate	SE	df	t-value	p-value
Intercept	0.835	0.121	52.8	6.923	<0.001*
Treatment (Green LED)	-0.019	0.141	29	-0.137	0.892
Net Type (Twine)	-0.313	0.173	52.8	-1.805	0.077^m
Treatment (Green LED) * Net Type (Twine)	-0.132	0.203	29	-0.649	0.522
Conditional R^2 = 0.414, Marginal R^2 = 0.144					
Blacktip Shark Complex	**Estimate**	**SE**	**df**	**t-value**	**p-value**
Intercept	0.691	0.117	43.9	5.909	<0.001*
Treatment (Green LED)	-0.018	0.162	22	-0.111	0.913
Net Type (Twine)	-0.361	0.159	43.9	-2.270	0.028*
Treatment (Green LED) * Net Type (Twine)	-0.037	0.220	22	-0.170	0.866
Conditional R^2 = 0.231, Marginal R^2 = 0.197					
Spot-tail Sharks	**Estimate**	**SE**	**df**	**t-value**	**p-value**
Intercept	0.231	0.069	32	3.355	<0.001*
Treatment (Green LED)	0.122	0.098	32	1.248	0.221
Net Type (Twine)	0.137	0.103	32	1.326	0.194
Treatment (Green LED) * Net Type (Twine)	-0.374	0.146	32	-2.560	0.015*
Conditional R^2 = 0.175, Marginal R^2 = 0.175					

(b)

Aggregated Elasmobranchs		Estimate	SE	df	t-ratio	p-value
	Monofilament	0.019	0.141	29	0.137	0.892
	Twine	0.151	0.146	29	1.036	0.309
Blacktip Shark Complex		**Estimate**	**SE**	**df**	**t-ratio**	**p-value**
	Monofilament	0.018	0.162	22.000	0.111	0.913
	Twine	0.056	0.149	22.000	0.372	0.713
Spot-tail Sharks		**Estimate**	**SE**	**df**	**t-ratio**	**p-value**
	Monofilament	-0.122	0.098	16	-1.248	0.230
	Twine	0.253	0.109	16	2.319	0.034*

(c) Hammerhead Sharks Grouped

Net Type	N. trials	Paired T-Test					Effect size (Cohen's d)
		Mean difference	95% CI	t	df	p-value	
Monofilament	8	-0.073	-0.687 – 0.542	-0.279	7	0.788	-0.099
Twine	4	-0.044	-0.204 - 0.116	-0.867	3	0.450	-0.434

Electric Deterrents

Bony Fish

There was no significant difference in CPUE between Treatment (Control vs. Electric Deterrent), Net Type (Monofilament vs. Twine) or the interaction for Aggregated Bony Fish or for Grey Mackerel ($p > 0.05$; Figure 13, Table 9). Grey Mackerel made up the majority of bony fish catches, resulting in negligible differences between models. The results suggests that Electric Deterrents had no discernible effect on catches of Bony Fish overall, or for Grey Mackerel specifically. However, variability between sets was very high (Table 11), so increased sampling is likely required to confirm a lack of effect.

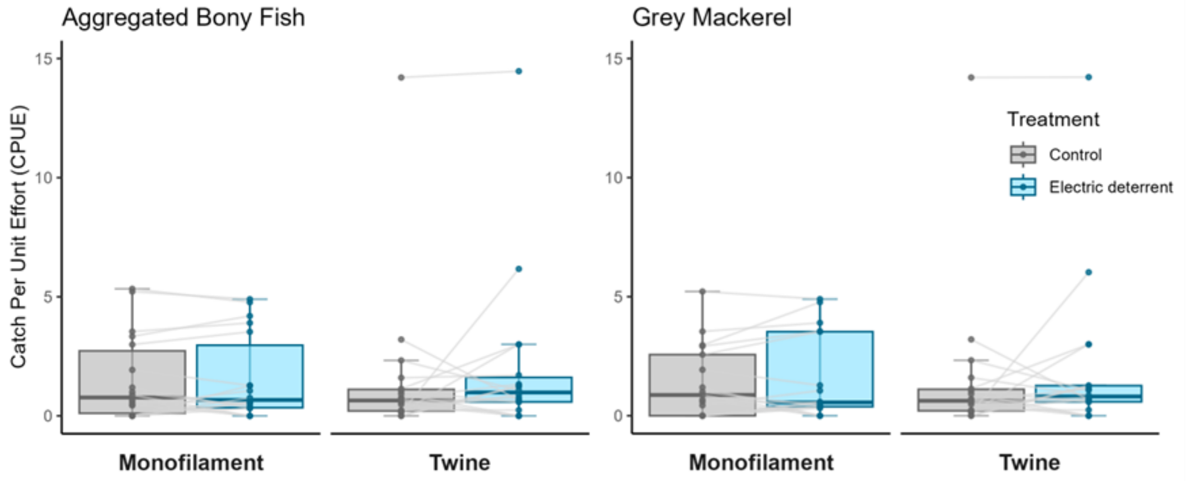


Figure 13. Boxplots showing catch per unit effort (CPUE) for Aggregated Bony Fish and Grey Mackerel caught during Electric Deterrent net deployments for the Fishery Dependent Trials in Monofilament and Twine nets. Points indicate raw CPUE data for each net with grey lines connecting data from net pairs (control and Electric Deterrent) for each deployment.

*Table 11. Table of summary statistics for comparisons between Control vs Electric Deterrent paired nets in Monofilament and Twine nets for Aggregated Bony Fish and Grey Mackerel. (a) Linear Mixed Effects Model results and (b) Estimated Marginal Mean Post-Hoc contrasts. NB: estimated marginal means are on the log(CPUE+1) transformed scale. * indicates a significant effect.*

(a)

Aggregated Bony Fish	Estimate	SE	df	t-value	p-value
Intercept	0.720	0.156	49.1	4.618	<0.001*
Treatment (Electric Deterrent)	0.027	0.136	34	0.197	0.845
Net Type (Twine)	-0.079	0.220	49.1	-0.360	0.720
Treatment (Electric Deterrent) * Net Type (Twine)	0.142	0.192	34	0.738	0.465
Conditional $R^2 = 0.623$, Marginal $R^2 = 0.008$					

Grey Mackerel	Estimate	SE	df	t-value	p-value
Intercept	0.699	0.159	48.1	4.400	<0.001*
Treatment (Electric Deterrent)	0.026	0.140	33	0.184	0.855
Net Type (Twine)	-0.061	0.221	48.1	-0.278	0.782
Treatment (Electric Deterrent) * Net Type (Twine)	0.112	0.195	33	0.571	0.572
Conditional $R^2 = 0.613$, Marginal $R^2 = 0.006$					

(b)

Aggregated Bony Fish	Estimate	SE	df	t-ratio	p-value
Monofilament	-0.027	0.136	34	-0.197	0.845
Twine	-0.169	0.136	34	-1.241	0.223
Grey Mackerel					
Monofilament	-0.026	0.140	33	-0.184	0.855
Twine	-0.137	0.136	33	-1.009	0.320

Elasmobranchs

There was no significant difference in CPUE between Treatment (Control vs. Electric Deterrent), Net Type (Monofilament vs. Twine) or the interaction for Aggregated Elasmobranchs (LMM: $p > 0.05$; Table 12a). However, a marginal effect of the Electric Deterrent was observed (LMM: $p = 0.064$), suggesting a potential effect across net types (Table 12a). Post-hoc analyses indicated this difference is driven by Monofilament nets, where CPUE was marginally higher (~31%) with Electric Deterrents compared to the Control ($p = 0.064$; Table 12a, Figure 14). There was a significant effect of the Electric Deterrent (LMM: $p = 0.027$; Table 12a) for Spot-tail Sharks, with CPUE significantly higher (~90%) in Monofilament nets fitted with Electric Deterrents compared to the Control ($p = 0.033$; Table 12b, Figure 14). For the Blacktip Shark Complex and Hammerhead Shark Group, no significant differences were found for Treatment or Net Type (Table 12a and c). However, for Hammerhead Sharks there was a moderate positive effect indicating a trend towards lower CPUE in Twine nets fitted with Electric Deterrents (Cohen's $d = 0.511$), although this was not significant (Table 12c, Figure 14).

The models for Aggregated Elasmobranchs and the Blacktip Shark Complex explained a substantial proportion of observed variation (Conditional $R^2 = 0.522$ and 0.337, respectively). However, the marginal R^2 values were low (0.055 and 0.036), indicating that most of the variation in CPUE was due to factors not captured by the fixed effects (Treatment of Net Type) (Table 12a). In contrast, the Spot-tail Shark model explained only 13.7% of the variation in CPUE, with little influence from Set ID (Marginal $R^2 = 0.137$; Table 12a).

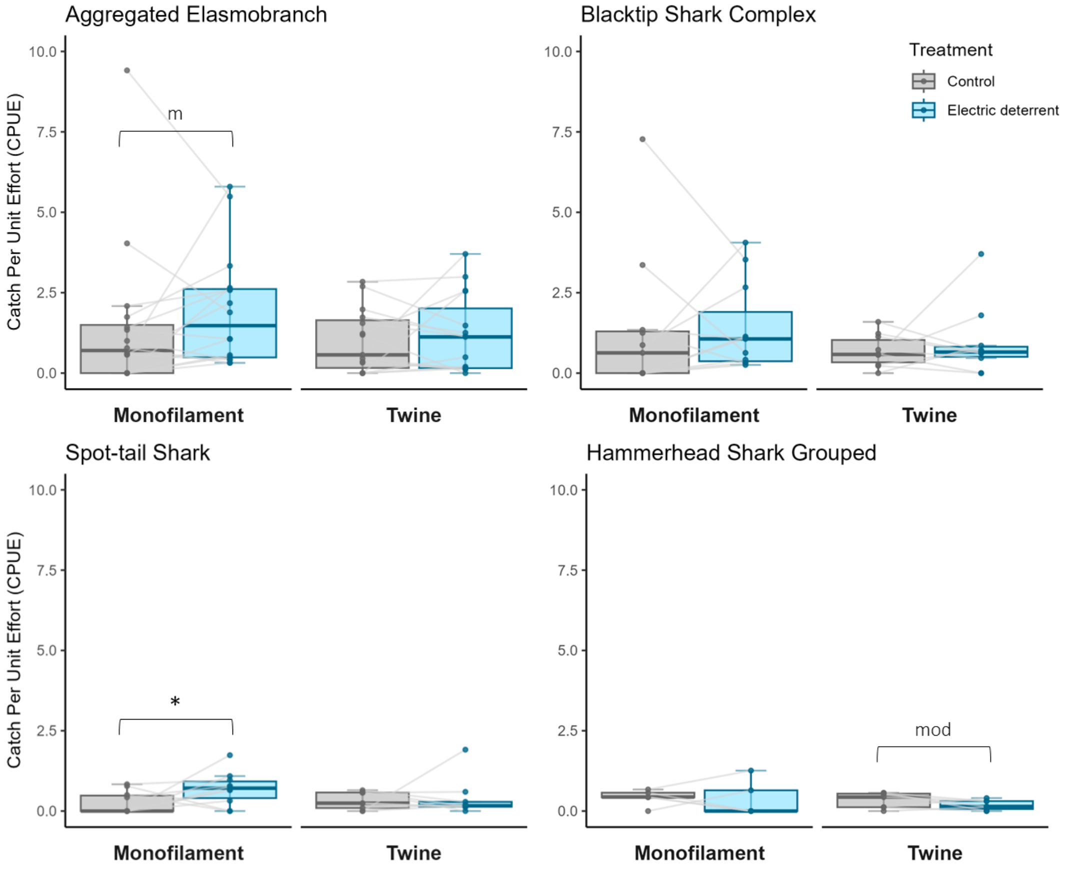


*Figure 14. Boxplots showing catch per unit effort (CPUE) for Aggregated Elasmobranchs, Blacktip Shark Complex, Spot-tail Sharks, and Hammerhead Sharks Grouped caught during Electric Deterrent net deployments for the Fishery Dependent Trials in Monofilament and Twine nets. Points indicate raw CPUE data for each net with grey lines connecting data from net pairs (control and Electric Deterrent) for each deployment. * = significant differences, m = marginally significant difference, mod = moderate effect (Hammerhead Sharks only).*

Overall, these results suggest that Electric Deterrents in Monofilament nets may increase CPUE for Spot-tail Sharks, while their use in Twine nets may have a slight deterrent effect on Hammerhead Sharks. No significant effects were observed for the Blacktip Shark Complex in either Net Type, which is the primary elasmobranch target of this fishery. However, variation between sets played a significant role in explaining the observed CPUE trends., therefore, further sampling is recommended to better understand observed effects.

*Table 12. Table of summary statistics for comparisons between Control vs Electric Deterrents paired nets in Monofilament and Twine nets for Aggregated Bony Fish. (a) Linear Mixed Effects Model results and (b) Estimated Marginal Mean Post-Hoc contrasts. NB: both the LMM and estimated marginal mean contrasts are on the log(CPUE+1) transformed scale. (c) Table of summary statistics for paired t-test for Hammerhead Sharks Grouped between Control vs Electric Deterrents for separate tests for each Net Type (Monofilament and Twine). * indicates a significant effect, m indicates a marginal effect.*

(a)

Aggregated Elasmobranch	Estimate	SE	df	t-value	p-value
Intercept	0.656	0.141	46.6	4.642	<0.001*
Treatment (Electric Deterrent)	0.274	0.142	29	1.929	0.064^{m}
Net Type (Twine)	-0.077	0.203	46.6	-0.381	0.705
Treatment (Electric Deterrent) * Net Type (Twine)	-0.198	0.204	29	-0.972	0.339
Conditional R^2 = 0.522, Marginal R^2 = 0.055					

Blacktip Shark Complex	Estimate	SE	df	t-value	p-value
Intercept	0.579	0.156	34.6	3.704	0.001*
Treatment (Electric Deterrent)	0.173	0.183	19	0.946	0.356
Net Type (Twine)	-0.093	0.226	34.6	-0.411	0.684
Treatment (Electric Deterrent) * Net Type (Twine)	-0.098	0.266	19	-0.370	0.715
Conditional R^2 = 0.337, Marginal R^2 = 0.036					

Spot-tail Shark	Estimate	SE	df	t-value	p-value
Intercept	0.194	0.089	34	2.187	0.036*
Treatment (Electric Deterrent)	0.291	0.126	34	2.314	0.027*
Net Type (Twine)	0.071	0.129	34	0.553	0.584
Treatment (Electric Deterrent) * Net Type (Twine)	-0.277	0.183	34	-1.516	0.139
Conditional R^2 = 0.137, Marginal R^2 = 0.137					

(b)

Aggregated Elasmobranchs	Estimate	SE	df	t-ratio	p-value
Monofilament	-0.027	0.136	34	-0.197	0.064^{m}
Twine	-0.169	0.136	34	-1.241	0.610

Blacktip Shark Complex	Estimate	SE	df	t-ratio	p-value
Monofilament	-0.173	0.183	19	-0.946	0.356
Twine	-0.075	0.192	19	-0.390	0.701

Spot-tail Shark	Estimate	SE	df	t-ratio	p-value
Monofilament	-0.291	0.126	17	-2.314	0.033*
Twine	-0.0139	0.133	17	-0.105	0.918

(c) Hammerhead Sharks

Net Type	N. trials	Paired T-Test					Effect size (Cohen's d)
		Mean difference	95% CI	t	df	p-value	
Monofilament	5	0.041	-0.708 - 0.789	0.150	4	0.888	0.067
Twine	7	0.148	-0.120 - 0.415	1.351	6	0.226	0.511

Conclusions

The Fishery-Dependent Trials assessed the effects of Green LED lights and Electric Deterrents on the catch rates (CPUE) of Bony Fishes and Elasmobranchs under commercial pelagic net fishery operations in the NT ONLF. Overall, the results indicate that neither device had a statistically significant effect on the catch rates of bony fish, including the key target species Grey Mackerel, across both Monofilament and Twine net types. However, high between-set variability suggests that a larger sample size is needed to robustly confirm the absence of effects on this species.

For elasmobranchs, the effects were more variable and species- and gear-specific. No significant effects were observed for the Blacktip Shark Complex, the main elasmobranch target species within the NT ONLF, for either device in any net type. For Spot-tail Sharks, a common target or byproduct species, Green LEDs significantly reduced CPUE in Twine nets, while Electric Deterrents significantly increased CPUE in Monofilament nets. For Hammerhead Sharks, no statistically significant differences in CPUE were detected; however, moderate effect sizes suggested a potential attractant effect of Green LEDs and a potential deterrent effect of Electric Deterrents in Twine nets. No such patterns were observed in Monofilament nets.

Importantly, despite the observed trends, variation between sets was high, indicating that unmeasured environmental or operational factors may strongly influence catch rates. This highlights the importance of conducting additional trials under a broader range of conditions to better understand the factors driving catch variability and to confirm emerging patterns.

While sample sizes were limited and variability between sets was high, meaning subtle or context-dependent effects cannot be confirmed with certainty, there was also no evidence of strong or consistent deterrent effects across species. Notably, none of the devices resulted in nil or consistently low catch rates compared to controls, suggesting that under the tested conditions, these deterrents are unlikely to elicit strong avoidance responses in either target or bycatch species. To confirm the absence of unintended effects on target species, larger-scale trials with greater statistical power are needed. For bycatch mitigation, more consistent and species-specific deterrent responses may require refinement of device design, deployment strategies, or targeting particular environmental or operational contexts. This will be critical for achieving broad-scale mitigation outcomes without compromising target catch.

Effects on fishery target species

Grey Mackerel, Blacktip Sharks, and Spot-tail Sharks are key target species for the NT ONLF. Both deterrent devices had no significant effect on the CPUE of Grey Mackerel or Blacktip Sharks across gear types. However, Spot-tail Sharks responded differently depending on the device and gear used. In Twine nets, Green LEDs significantly reduced Spot-tail Shark CPUE. This outcome may be due to the Green LEDs enhancing the visibility of the green twine net, which could deter Spot-tail Sharks from approaching closely enough to become entangled. As this effect was not observed in monofilament nets, this may indicate that for Spot-tail Sharks Green LEDs are not as effective in this gear which has lower overall visibility. Conversely, in Monofilament nets, Spot-tail Shark CPUE was significantly higher when Electric Deterrents were used. A possible explanation is that the pulsed electric field emitted by the deterrents may have attracted Spot-tail Sharks, either directly through curiosity-driven investigation of the stimulus or indirectly by influencing the behaviour of prey. While electric deterrents are generally designed to repel electroreceptive species, weak fields may elicit exploratory behaviours in some sharks. The absence of this effect in Twine nets could be due to increased gear visibility reducing entanglement likelihood, even if attraction occurred.

These findings highlight the potential for species- and gear-specific interactions with mitigation devices, which may influence catch composition and should be considered in management decisions where both target yield and conservation objectives are important. Although the primary elasmobranch target, the

Blacktip Shark Complex, showed no significant response, the variable effects on Spot-tail Sharks suggest that even within target groups, mitigation technologies may have unintended effects.

Deterrence potential for TEPS and Species of Conservation Interest

Primary elasmobranch TEPS interacting with fishing operations in the NT ONLF include four species of sawfish (*Pristis clavata, P. zijsron*, *P. pristis* and *Anoxypristis cuspidata*), mobulid rays (*Mobula* spp.), and River Sharks (*Glyphis* spp.). Other TEPS include dolphins, dugongs, turtles, and estuarine crocodiles. During this study, only a single individual of a TEP species, a Longhorned Pygmy Devil Ray (*Mobula eregoodoo*), was encountered. This is consistent with the generally low interactions with TEPS reported for this fishery (Kimlin, 2024), but the small number of encounters negated our ability to evaluate the effects of the deterrents on catch rates for TEPS.

Hammerhead Sharks (Great, Scalloped, and Winghead) are taken as secondary species in the NT ONLF but are considered here as species of conservation interest (DCCEEW, 2024; FRDC, 2023a). As of January 2024, Hammerhead species are now considered no-take in Queensland, including within the Gulf of Carpentaria Fin Fish Fishery, which is operationally very similar to the NT ONLF. Hammerhead Sharks were encountered in reasonable numbers during the trials. While no statistically significant effects were detected for either deterrent device, Green LEDs in Twine nets were associated with moderately higher CPUE, suggesting a potential attractant effect. Conversely, Electric Deterrents in Twine nets were associated with a moderate reduction in CPUE, indicating a possible deterrent effect. These effects were not observed in Monofilament nets. Given the conservation concerns surrounding Hammerhead Sharks, even the moderate trends observed here warrant further investigation. The results suggest that Twine nets fitted with Electric Deterrents may offer some mitigation potential for these species, but further trials with increased sample sizes are needed to clarify the magnitude and consistency of these effects before they can be recommended for implementation.

Experimental limitations

This study encountered several limitations that should be considered when interpreting the results. The sample size was relatively low (19 sets), and catch rates showed high variability between sets, which likely reduced the statistical power to detect subtle effects. Additionally, interactions with TEPS were rare, preventing any meaningful assessment of deterrent effects on these species. The study also utilised both monofilament and twine nets, although monofilament nets are more representative of typical gear used in pelagic net fisheries. This may limit the generalisability of the findings to the broader NT ONLF or other commercial net fisheries. Despite these limitations, the study provides preliminary evidence that the deterrent devices tested have negligible effects on key target species, with the exception of Spot-tail Sharks, while potentially influencing catch rates for species of conservation interest, such as Hammerhead Sharks. Further research with increased replication and broader environmental coverage is recommended to validate and expand upon these findings prior to recommending the devices for broader implementation.

Industry implications

The results suggest that while Green LEDs and Electric Deterrents may not significantly impact catch rates of key target species, there are species-specific responses that should be considered in the context of fishing operations. For example, interactions with Hammerhead Sharks may vary depending on the deterrent and net type. The variability observed in catch rates highlights the need for further testing at wider scales to fully understand the potential effect of the deterrents on catch rates for target and bycatch species, to fully understand the operational and ecological trade-offs of these devices before broader implementation in commercial gillnet fisheries is considered.

Operationally, the crew reported no significant challenges in using the devices during the trials. Attaching them to floats or the float line integrated smoothly into net deployment.; however, during retrieval, the devices or clips occasionally became entangled in the mesh, slowing the process. To improve efficiency, permanently attaching the device cases to the float line or net would allow for easily swapping out devices as required. However, the durability of the cases under winch strain and net drum pressure must be considered. The soft plastic cases for the Green LED devices are likely to withstand these forces, whereas the hard polymer cases for the Electric Deterrents may not.

Recommendations

The findings from the Fishery-Dependent Trials provide valuable insights into the effects of Green LED lights and Electric Deterrents on catch rates of both bony fish and elasmobranchs in the NT ONLF. However, the observed variability, particularly regarding species-specific responses and the low sample size, suggests that further research is necessary to confirm the trends identified and optimise the use of these technologies in commercial fisheries. Based on the findings, implementation of these devices in commercial setting is not currently recommended without further testing. Key recommendations for future studies include:

- **Increased Sampling and Replication**: Given the high variability between sets, further trials with increased replication are essential to confirm trends observed and improve generalisability of the results. This will help clarify the effects of Green LEDs and Electric Deterrents on both target and bycatch species, particularly for species like Hammerhead Sharks, which may be more sensitive to these devices. Longer-term trials in a commercial setting will assist in increasing sample sizes for TEPS to fully understand their bycatch reduction potential.
- **Species-Specific Strategies**: Given the species-specific effects observed, further research is needed to understand how deterrent devices can be optimised for different species, especially conservation-sensitive species like Hammerhead Sharks.
- **Device Durability and Practicality**: Based on feedback from the fishing crew, there are operational challenges related to device entanglement during net retrieval. Future trials should explore the feasibility of permanently attaching the deterrent devices to the float line or net, enabling easier swapping of devices as batteries are depleted. Additionally, the durability of the device cases under winch strain and net drum pressure needs further assessment. Soft rubber cases for Green LED devices are likely suitable, whereas the hard polymer cases for Electric Deterrents used may require redesign.
- **Further Investigation into TEPS and Conservation Species**: Interactions with TEPS were rare in this study, limiting conclusions about bycatch reduction for threatened species. Future research should prioritise trials in areas or seasons with higher TEPS encounter rates to properly evaluate deterrent effects on focal threatened species such as Sawfish, Mobulid rays, and River Sharks.

Overall, while this study did not identify strong or consistent deterrent effects from Green LEDs or Electric Deterrents, it also did not detect significant negative impacts on catch rates of key target species. These findings suggest that, under the conditions tested, the devices are unlikely to compromise target catch performance. However, neither device consistently reduced catch of species of conservation interest, indicating that further refinement, either in device design or deployment method, may be necessary to realise bycatch mitigation benefits. To confirm the absence of impacts on target species, expanded trials with higher replication are essential. At the same time, identifying stronger and more consistent responses in threatened species will be key to developing these devices into effective bycatch reduction tools suitable for broader implementation in commercial gillnet fisheries.

Alternative Gear Assessment

The Alternative Gear Assessment aimed to address *Objective 2: Assess alternative gears to gillnets in the Northern Territory Barramundi Fishery*, with a particular focus on identifying gear options that could reduce bycatch of threatened species. Through review and critique of alternative fishing gears, the assessment aimed to provide industry with information on potential pathways to move beyond gillnetting in the future should suitable alternative gear be identified, evaluated, and tested (noting that testing was outside the scope of this project). While the assessment focused on the commercial sector of the NT Barramundi Fishery, but the outcomes are applicable across all northern Australian gillnet fisheries.

The Alternative gear Assessment included two components: (1) a Desktop Review to establish an evidence base for potential alternative gear options; and (2) a Workshop to assess their practicality and feasibility in the operational setting of the NT Barramundi Fishery.

Desktop Review

The Desktop Review compiled evidence on alternative gears, considering their threatened species interactions and mitigation strategies, and key environmental, social, economic, and operational factors for each gear. Legislative and policy considerations relating to the NT Barramundi Fishery were considered beyond the scope of this review. The ongoing uncertainty surrounding the fishery that have arisen following the announced phase-out of gillnets in the commercial sector of the NT Barramundi Fishery in August 2024 made it difficult to define policy and legislative requirements at the time of the Alternative Gear Assessment. Future work should address these aspects once a shortlist of alternative gears is identified, with fisheries managers collaborating closely with industry to ensure clarity and support during the transition.

A comprehensive report was produced for the Desktop Review of Alternative Gears, including Gear Summaries for each gear reviewed. The desktop review canvassed available literature and key fisheries research and management resources to develop an overview of alternative gear options. For each gear type identified, the following information was included:

- Description of the gear, its design, and operation.
- Relevant fisheries currently using the gear commercially in similar regions, environments, and/or for similar target species.
- Comparisons to commercial gillnets, if available.
- Environmental considerations, including environmental impacts, such as interactions with TEPS, and current mitigation actions.
- Economic considerations, including catch quality and catch per unit effort information, setup and maintenance costs, and gear and crew requirements.
- Social considerations, including public perceptions and potential conflict with other sectors.

Alternative gears considered in the review were restricted to those currently used in commercial marine and coastal wild capture fisheries targeting finfish. Innovative gears, less established techniques, and gears used only in limited or specialised contexts were not considered. By focusing on proven gears, the review sought to provide practical, implementable options for industry, and ensured industry were offered viable gear options that are:

- **Readily available**: Gears that are already accessible in the market allow for quicker adoption and lower barriers to entry.
- **Adaptable to specific fishing contexts**: Well-known gears have demonstrated their ability to be customised to meet the needs of different fisheries.

- **Known interaction rates with threatened species**: These gears have established interaction profiles with threatened species, including well-researched and tested bycatch mitigation strategies.
- **Known environmental, social, and economic impacts**: The effects of these gears are documented, providing a clearer understanding of their benefits and drawbacks.

Alternative gears were first identified using the International Standard Statistical Classification of Fishing Gear (ISSCFG) (FAO, 2016) and further definitions provided in He et al. (2021). An initial screening was conducted to exclude innovative gears, less established techniques, and gears used only in limited or specialised contexts, and then gears considered sufficiently similar were grouped together for the review. The resulting list of gears reviewed included 9 gears across 3 gear categories:

- **Net-based gears:**
    - Surrounding nets (purse seines and lampara nets)
    - Beach seines
    - Boat seines
    - Trawls
- **Trap gears:**
    - Pound nets or arrowhead traps
    - Tunnel nets
    - Fish pots
- **Hook and line gears:**
    - Simple hook and line gears
    - Multi-hook line gears

The full Desktop Review Report can be found in Pini-Fitzsimmons, J., Amini, S. & Grimes, J. 2025. Alternative Gear Desktop Review: A review of alternative gears for the commercial sector of the Northern Territory Barramundi Fishery. https://www.cdu.edu.au/files/2025-03/Alternative-gear-desktop-review-report.pdf

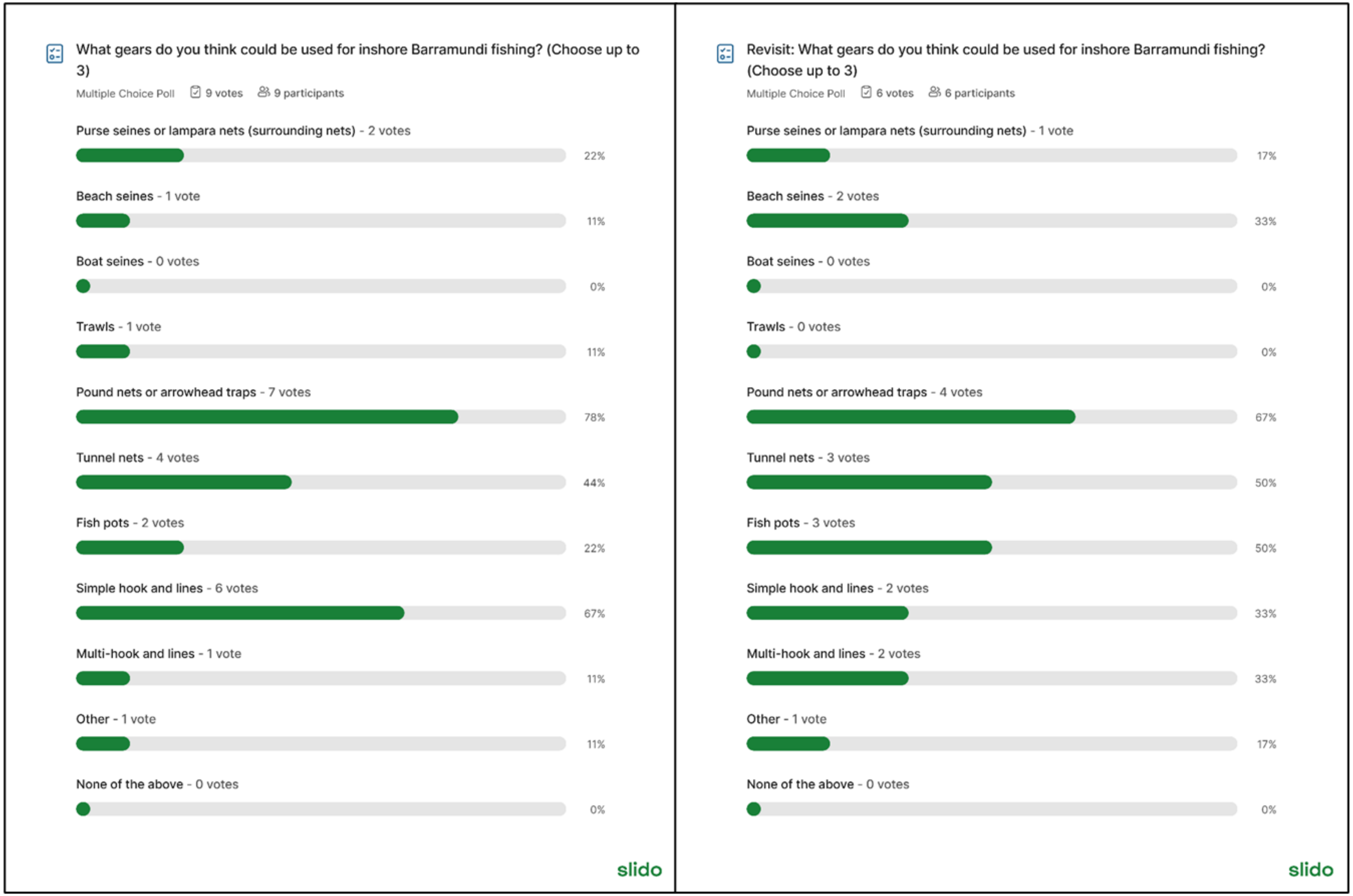
Workshop

The workshop was held online on 27 March 2025, engaging industry representatives, fisheries managers, and scientists. Its primary objective was to present findings from the Desktop Review on alternative fishing gears and discuss their feasibility for implementation in the NT Barramundi Fishery. Invitations were extended to key stakeholders, including the Northern Territory Seafood Council, NT Department of Agriculture and Fisheries (NT DAF), NT Barramundi Fishery representatives (license holders, lessees, crew, including the Aboriginal Sea Company), the Fisheries Research and Development Corporation (FRDC), and the project lead for the Fish LIGHT project led by the Queensland Department of Primary Industries.

Nine representatives attended, including NT Barramundi Fishery industry members, NT DAF, FRDC, and the Fish LIGHT Project lead. The timing coincided with the fishing season, limiting attendance; however, workshop materials, including the Desktop Report, gear summaries, and slide deck, were shared with all invitees.

The workshop consisted of a presentation provided by Dr Joni Pini-Fitzsimmons, which included an overview of the broader project and alternative gears identified in the Desktop Review, followed by an open discussion.

Using the Slido.com platform, participants were presented with two polls on potential gears for inshore Barramundi fishing, one before and one after the presentation to understand which Alternative Gears were of greatest interest within the NT Barramundi Fishery and to determine if these preferences had shifted following the presentation of information relating to alternative gears from the Desktop Review (Figure 15).



What gears do you think could be used for inshore Barramundi fishing? (Choose up to 3)

Multiple Choice Poll 9 votes 9 participants

Purse seines or lampara nets (surrounding nets) - 2 votes 22%

Beach seines - 1 vote 11%

Boat seines - 0 votes 0%

Trawls - 1 vote 11%

Pound nets or arrowhead traps - 7 votes 78%

Tunnel nets - 4 votes 44%

Fish pots - 2 votes 22%

Simple hook and lines - 6 votes 67%

Multi-hook and lines - 1 vote 11%

Other - 1 vote 11%

None of the above - 0 votes 0%

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Revisit: What gears do you think could be used for inshore Barramundi fishing? (Choose up to 3)

Multiple Choice Poll 6 votes 6 participants

Purse seines or lampara nets (surrounding nets) - 1 vote 17%

Beach seines - 2 votes 33%

Boat seines - 0 votes 0%

Trawls - 0 votes 0%

Pound nets or arrowhead traps - 4 votes 67%

Tunnel nets - 3 votes 50%

Fish pots - 3 votes 50%

Simple hook and lines - 2 votes 33%

Multi-hook and lines - 2 votes 33%

Other - 1 vote 17%

None of the above - 0 votes 0%

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Figure 15. Results of Slido.com polls asking workshop attendees “What gears do you think could be used for inshore Barramundi Fishing?”. The first (left) was posed before the review of gears was presented, while the second (right) was posed afterwards.

Initially, ‘pound nets or arrowhead traps’ received the most interest, followed by ‘simple hook and lines’ and ‘tunnel nets’ (Figure 15). Post-presentation, ‘pound nets or arrowhead traps’ remained the top choice, with increased interest in ‘tunnel nets’ and ‘fish pots’ (Figure 15), suggesting a high level of interest in passive fishing gears. The ‘Other’ category was selected by one attendee when the poll was first posed, which was identified as ‘Grassl electrofishing’. This refers to newer adaptations of traditional electrofishing gear (traditionally restricted to freshwater environments) that have proven effective in estuarine and brackish-water environments (e.g., Grassl electrofisher, Lieschke et al. (2019)). Post-presentation, there was a single vote for ‘Other’, but this was not specifically identified at the time. Importantly, reducing threatened species interactions or effective mitigation options was a key consideration in gear choice.

Participants also received an update on the Fish LIGHT Project (FRDC Project 2023-154), led by Queensland DAF. This initiative trials and evaluates alternative low-impact fishing technologies for Queensland’s inshore fisheries (East Coast and Gulf of Carpentaria) and provides insights into how other jurisdictions are managing gillnet phase-outs and an opportunity to share lessons learnt to date. While the project extends beyond Barramundi fishing, its findings are highly relevant to the NT Barramundi Fishery. Considerable consultation has already taken place, and field trials of alternative gears are well underway. The update covered the following alternative gears currently being tested:

- **Fish pots/traps**: 10 designs of fish pots/traps, including industry-designed concepts, are currently being considered..
- **Tunnel nets**: Site scoping is underway, extending preliminary work conducted by Chin et al. (2022).
- **Trap-nets**: Likened to a portable pound net or arrowhead trap-type gear (e.g., End of Spring Trap Netting, Ontario; Ontario Ministry of Natural Resources (2004)), these gears are being considered over more permanent traps due to logistical constraints with use of permanent structures.
- **Simple hook and line fishing**: Collaboration underway with ~20 line fishers targeting Barramundi to understand economic viability
- **Electrofishing**: Novel applications for estuarine and saltwater environments are being explored, but a lack of understanding into the sublethal effects was noted.

When asked there were any other gears not yet discussed that were of interest within the NT Barramundi Fishery, the following gears were raised by attendees:

- **Net-based pulley systems** currently used in the Northern Territory under Aboriginal Coastal Fishing Licenses (e.g., Maningrida Homelands Coastal Fishing Business, Wilton et al. (2018))
- **Spotlighting** for targeting fish in rivers at night with a spear or arrow.
- **Live bait longlining** to minimise shark bycatch (NB: unable to verify this statement).
- **Removable trap ends** for pound nets or arrowhead traps.

Considering the gears discussed, several key operational considerations were highlighted by participants. Notably, some of the highest-ranked alternative gears, such as arrowhead traps, are designed for use in intertidal zones. Given that a significant portion of the NT’s intertidal waters is under Indigenous ownership or claim, Section 19 agreements will be required to operate these gears unless viable subtidal designs can be developed.

Participants also discussed refining existing gillnet practices in the interim, such as reducing soak times, improving net attendance, and implementing electronic monitoring to mitigate threatened species interactions while the transition to alternative gears was underway. It was highlighted that these measures, already in use in Queensland under temporary NX licenses used to assist the transition away from gillnets (Queensland Government, 2024c), have been shown to improve fishing practices and sustainability. While industry expressed support for adopting similar measures in the NT Barramundi Fishery, they noted that these measures might be redundant given the NT Government’s plan to phase out gillnets within three years.

Conclusions

The Alternative Gear Assessment provided critical insights into potential options for transitioning the Northern Territory Barramundi Fishery away from gillnets. The Desktop Review established an evidence base for a range of alternative gear types currently used in commercial marine and coastal wild capture fisheries, while the workshop facilitated direct engagement with key industry representatives, fisheries managers, and researchers. Discussions highlighted industry perspectives on gear feasibility and operational constraints that must be considered during the transition away from gillnets. Reduced threatened species interactions and the availability effective mitigation options was a key consideration in gear choice.

The assessment, particularly the workshop, highlighted strong industry interest in alternative gears, particularly passive fishing gears such as pound nets, tunnel nets, and fish pots, which aligns with work underway in Queensland with respect to alternative gears for inshore gillnet fishing, while also identifying key operational challenges in the specific context of the NT Barramundi Fishery. Discussions underscored the importance of gear trials, knowledge-sharing, and a structured transition strategy to support the long-term sustainability of the NT Barramundi Fishery.

Based on the outcomes of the Alternative Gear Assessment, the following recommendations are proposed to support the transition from gillnets to alternative gears in the NT Barramundi Fishery:

- **Regulatory and policy clarity**: Fisheries managers need to clarify legislative and policy requirements for NT Barramundi Fishery's transition away from gillnets, ensuring regulatory pathways are established for adopting new fishing methods.
- **Pilot trials and field testing:** Conduct targeted pilot trials of the most promising alternative gears (pound nets, tunnel nets, and fish pots) in collaboration with industry. Trials should assess catch efficiency, species selectivity, threatened species interactions and mitigation, commercial viability, and social acceptability.
- **Exploration of emerging fishing technologies:** Support further exploration of innovative gears and technologies such as marine electrofishing, improved trap designs, and bycatch reduction innovations.
- **Sustainable use of gillnets:** Recognise that gillnets will continue to be used during the transition, and interim efforts focusing on ensuring best practices for sustainability and reducing TEPS interactions should be implemented, including reduced soak times, increased net attendance, and mandatory electronic monitoring.

Conclusions & Recommendations

Key findings

Bycatch Mitigation Device Trials

This project evaluated the effectiveness of Green LED lights and Electric Deterrents as bycatch mitigation devices for elasmobranchs, with a focus on threatened species (TEPS), through a combination of (1) aquarium trials to examine behavioural responses of elasmobranchs, (2) fishery-independent trials to test the effects of these devices under controlled field conditions, and (3) fishery-dependent trials to assess their performance in commercial gillnet operations. Results indicate species- and context-specific effects for both Green LEDs and Electric Deterrents (summarised in Table 13). Green LEDs showed both deterrent and attractant effects depending on the species and net type, with potential as a sawfish bycatch mitigation tool that requires further testing. Electric Deterrents showed inconclusive but promising trends, including possible deterrent effects for sawfish (in monofilament nets) and Hammerhead Sharks (in twine nets), suggesting further investigation is needed.

Importantly, while subtle species- and gear-specific patterns were observed, no strong or consistent deterrent effects were evident across trials. Neither Green LEDs nor Electric Deterrents resulted in consistently reduced or nil catch rates for any species compared to control nets. This suggests that, under the conditions tested, these devices are unlikely to elicit strong avoidance responses in either target or non-target species, including TEPS. While some promising trends were identified, particularly for sawfish and Hammerhead Sharks, the results did not demonstrate consistent or broadly applicable reductions in bycatch across fisheries or gear types. As such, the devices are not currently considered suitable for bycatch mitigation in gillnets, or pelagic nets, in their current form. Further research with larger sample sizes is required to optimise their design and fully assess potential impacts on target, byproduct, and bycatch species before commercial adoption should be considered.

Aquarium Trials

Green LEDs showed some deterrence for Giant Shovelnose Rays (*Glaucostegus typus*), but these rays were still frequently observed making contact with experimental nets (Table 13). No deterrent effects were detected for Brownbanded Bamboo Sharks (*Chiloscyllium punctatum*) with either device. While the response of Shovelnose Rays is noteworthy, given their morphological and ecological similarities to highly threatened sawfishes, the findings for this component alone do not provide strong evidence that Green LEDs offer sufficient deterrence for broad implementation in commercial gillnetting.

Fishery-Independent Trials

The fishery-independent trials allowed for testing of devices in real-world conditions, similar to those encountered when commercially targeting Barramundi and Threadfin Salmon (e.g., intertidal waters with high turbidity). The trials showed variable species responses. Gillnets with Green LEDs generally had lower elasmobranch catches, but catches of Graceful Sharks (*Carcharhinus amblyrhynchoides*), a typical byproduct species, were significantly increased (Table 13). Notably, there was a trend towards lower sawfish catches in Green LED nets and Electric Deterrent nets, suggesting a potential deterrent effect (Table 13), though small sample sizes limit the ability to draw definitive conclusions. Despite this, these results indicate that further study of the capacity of these devices for deterring sawfish catches in gillnets is warranted.

Effects on target species were also varied. Green LEDs appeared to increase catches of bony fish, particularly Blue Threadfin (*Eleutheronema tetradactylum*), while potentially deterring King Threadfin (*Polydactylus macrochir*) (Table 13). No effect was observed for Barramundi (*Lates calcarifer*) (Table 13).

Electric Deterrents had inconclusive results due to low replication but showed potential trends for increased Barramundi catches and reduced King Threadfin catches.

*Table 13. Summary of effects observed during Bycatch Mitigation Device Trials across species and groups. Significant effects are denoted by ***. N.S. = not significant. Significant and marginal deterrent effects are highlighted in dark red and light red, while significant and marginal attractant effects are highlighted in dark blue and light blue, respectively.*

			Green LED		Electric Deterrent	
Trial	Species or group		Effect	Significance	Effect	Significance
Aquarium Trials	Giant Shovelnose Ray *Glaucostegus typus*		Higher chance deterred compared to control	***	No effect observed	
	Brownbanded Bamboo *Chiloscyllium punctatum*		No effect observed		No effect observed	
			Green LED		Electric Deterrent	
			Effect	Significance	Effect	Significance
Fishery-Independent Trials	Aggregated Bony Fish		Higher CPUE	***	No effect observed	
	Barramundi *Lates calcarifer*		No effect observed		Higher CPUE	Moderate effect, N.S.
	Blue Threadfin *Eleutheronema tetradactylum*		Higher CPUE	Large effect, N.S.	No effect observed	
	King Threadfin *Polydactylus macrochir*		Lower CPUE	Moderate effect, N.S.	Lower CPUE	Moderate effect, N.S.
	Aggregated Elasmobranchs		Lower CPUE	Marginal	No effect observed	
	Whaler Sharks *Carcharhinus* spp.		No effect observed		No effect observed	
	Blacktip Shark Complex *Carcharhinus limbatus & C. tilstoni*		No effect observed		Not assessed	
	Graceful sharks *C. amblyrhynchoides*		Higher CPUE	***	No effect observed	
	Pigeye Sharks *C. amboinensis*		No effect observed		No effect observed	
	Nervous Sharks *C. cautus*		No effect observed		No effect observed	
	Sawfish grouped *Anoxypristis cuspidate, Pristis clavata & P. zijsron*		Lower CPUE	Moderate effect, N.S.	Lower CPUE	Moderate effect, N.S.
			Green LED		Electric Deterrent	
			Effect	Significance	Effect	Significance
Fishery-Dependent Trials	Aggregated Bony Fish	Twine	No effect observed		No effect observed	
		Monofilament	No effect observed		No effect observed	
	Grey Mackerel *Scomberomorus semifasciatus*	Twine	No effect observed		No effect observed	
		Monofilament	No effect observed		No effect observed	
	Aggregated Elasmobranchs	Twine	No effect observed		No effect observed	
			Significantly lower CPUE in Twine nets overall			
		Monofilament	No effect observed		Higher CPUE	Marginal
	Blacktip Shark Complex *C. limbatus & C. tilstoni*	Twine	No effect observed		No effect observed	
			Significantly lower CPUE in Twine nets overall			
		Monofilament	No effect observed		No effect observed	
	Spot-tail Sharks *C. sorrah*	Twine	Lower CPUE	***	No effect observed	
		Monofilament	No effect observed		Higher CPUE	***
	Hammerhead Sharks grouped Sphyrnidae	Twine	Higher CPUE	Moderate effect, N.S.	Lower CPUE	Moderate effect, N.S.
		Monofilament	No effect observed		No effect observed	

Fishery-Dependent Trials

Conducted under standard operations within the NT Offshore Net and Line Fishery, these trials tested the devices in pelagic net settings using both monofilament and green twine nets. Unfortunately, only one TEPS (a Longhorned Pygmy Devil Ray, *Mobula eregoodoo*) was caught, preventing meaningful evaluation of TEPS deterrence. However, catch rates for Hammerhead Sharks, a species of conservation concern, showed evidence of contrasting responses in twine nets (Table 13). Green LEDs appeared to have an attractant effect, while Electric Deterrents showed a potential deterrent effect. No effects were seen in monofilament nets, which are more commonly used in northern Australian gillnet fisheries.

While effects on TEPS remain uncertain, impacts on target species were clearer (Table 13). Neither Green LEDs nor Electric Deterrents affected catches of Grey Mackerel (*Scomberomorus semifasciatus*) or Blacktip Sharks (*Carcharhinus limbatus* and *C. tilstoni*). However, Spot-tail Shark (*C. sorrah*) catches were significantly lower in twine nets with Green LEDs (suggesting a deterrent effect) and significantly higher in monofilament nets with Electric Deterrents (suggesting an attractant effect). This highlights the need for careful consideration of both net type and mitigation device in fisheries targeting this species.

Alternative Gear Assessment

The Alternative Gear Assessment provided valuable insights into potential options for transitioning the Northern Territory Barramundi Fishery away from gillnets, and revealed significant interest from industry in future-proofing the NT Barramundi Fishery through exploring alternative gears. Passive fishing gears, such as pound nets, tunnel nets, and fish pots, were identified as promising alternatives, which aligned with current alternative gear assessments occurring in Queensland. The assessment emphasised the need to consider operational constraints and feasibility within the specific context of the NT Barramundi Fishery when adopting new gears. Discussions highlighted the need for targeted gear trials, the importance of knowledge-sharing and collaborative approaches to selecting alternative gears for trialling, and the need for a structured transition strategy for the NT Barramundi Fishery that supports industry in the transition away from gillnets.

Impact and Implications

Bycatch Mitigation Devices

This project provides valuable insights into the potential use of Green LED lights and Electric Deterrents as bycatch mitigation devices for elasmobranchs, particularly threatened species such as sawfish. The findings suggest that both devices could help reduce bycatch of sawfish and potentially other species, such as hammerhead sharks, offering a pathway toward more sustainable gillnet fishing practices. However, the effectiveness of these devices varied by species, net type, and fishing context.

For commercial fishers, this variability means that while these technologies show promise, neither can yet be considered a reliable or generalised solution. For example, Green LEDs showed potential for deterring sawfish, while also increasing catches of certain bony fish, such as Blue Threadfin, and potentially deterring King Threadfin in nearshore environments typical of Barramundi fishing. Electric Deterrents also indicated potential deterrent effects for threatened sawfish in inshore fishing contexts, but did show more inconclusive results than Green LEDs. Importantly, neither device negatively affected target species such as Grey Mackerel or Blacktip Sharks in a pelagic net fishing setting, meaning they could be adopted without significant loss to fishers' catches of these commercially valuable species. However, other species-specific effects were observed, that could pose potential trade-offs. For example, Spot-tail Sharks were less frequently caught in twine nets with Green LEDs, but more frequently in monofilament nets with Electric Deterrents. This highlights the potential for unintended economic impacts depending on target species and gear choice. These nuances underscore the need to match mitigation strategies to the ecological and operational context of each fishery.

While preliminary trends are encouraging, particularly for Sawfish and Hammerhead sharks, results across all trials were limited by small sample sizes and inconsistent species responses. Importantly though, neither device consistently reduced catch rates relative to controls. This suggests that strong avoidance responses are unlikely under the conditions tested. As such, neither tool can yet be recommended for broad-scale implementation, and further refinement, testing, and validation are essential, and worth exploring given observed trends for species such as sawfish.

Widespread adoption of these devices faces several challenges. The uncertain effectiveness of the devices across different species and fishing environments may make it difficult for fishers to commit to their use without clearer, more definitive evidence of their benefits. Additionally, the costs associated with implementing these tested technologies would likely impede adoption, especially if the devices do not deliver guaranteed reductions in bycatch or improvements in fishery outcomes. While green LED lights specifically designed for use in fishing gear are relatively accessible and affordable (typically under AU$20 per unit), electric deterrents remain in early stages of development and are likely to be cost-prohibitive. A further complication is the need to determine the most appropriate configuration of devices, which will affect how many are required per net. This could not be assessed in the current study and would have important cost and operational implications. Based on current findings, neither Green LEDs nor Electric Deterrents are currently considered suitable for use implementation as bycatch mitigation tools in gillnet or pelagic net fisheries in northern Australia without further refinement and validation.

Future work should include incentives for further trials and data collection, as well as support for fishers transitioning to bycatch reduction technologies if and when an effective strategy is identified. Furthermore, collaboration between fishers, researchers, and fisheries managers is critical to ensuring that bycatch reduction strategies are scientifically informed, economically viable, and practical in real-world commercial fishing operations.

While this study does not identify a 'silver bullet' for reducing bycatch in northern Australian gillnet fisheries, it provides a strong foundation for future innovation. Both Green LEDs and Electric Deterrents showed potential in specific contexts, particularly for species of conservation concern. Continued collaborative research will be essential to refining these tools and developing mitigation strategies that are ecologically effective, economically viable, and operationally practical.

Alternative Gears

The Alternative Gear Assessment provides a foundation for transitioning the NT Barramundi Fishery away from gillnets, offering industry and fisheries managers evidence-based insights into alternative fishing gear options. For industry, the assessment highlights both opportunities and challenges. While alternative gears that had the greatest interest, like pound nets, tunnel nets, and fish pots offer potential benefits, including improved selectivity and sustainability, regulatory uncertainty and operational constraints present barriers to uptake. Given recent calls for the phase out of gillnets in the commercial sector of the NT Barramundi Fishery within 3 years, regulatory clarity, knowledge-sharing, and structured pilot trials are essential to overcome these barriers and ensure sustainability of the fishery moving forward. This includes the need for supporting innovation in emerging fishing technologies, industry-led trials, and a phased transition that includes improved practices for gillnets still in use during the transition. These measures will be key to balancing economic viability with conservation goals in the NT Barramundi Fishery in the long-term.

Recommendations and Next Steps

Efficacy of Bycatch Mitigation Devices

The findings from this project highlight the potential of Green LED lights and Electric Deterrents to reduce bycatch and influence catch composition in commercial gillnet fisheries. However, the effectiveness of these devices varied by species and across fishing conditions, and neither device resulted in consistent or broadly applicable bycatch reductions. Based on current evidence, these technologies are not considered suitable for use as bycatch mitigation tools in set nets, gillnets, or pelagic nets in their current form. Despite promising results for vulnerable species, such as Sawfish and Hammerhead Sharks, further research is necessary to better understand their efficacy, refine their design, and assess practical applications before they can be recommended for operational use. The following recommendations outline key steps to build on this research:

1. Expand field trials to improve statistical power and generalisability

The current study revealed promising trends but was limited by small sample sizes and high variability in catch compositions. To strengthen confidence in the results and provide clearer guidance for industry implementation, future research should involve larger-scale trials with increased replication across relevant fisheries, multiple fishing seasons, and a broader range of environmental conditions. Expanded trials within specific fisheries, such as those targeting Barramundi and Grey Mackerel, will help clarify how these deterrents interact with target and non-target species within these specific fishing contexts. It is also important to assess potential habituation to deterrents over time, as declining effectiveness with repeated exposure could limit their long-term value. Long-term trialling is necessary to determine whether deterrents can offer reliable and sustainable bycatch reduction.

2. Assess Species-Specific Responses to Optimise Device Design and Deployment

The effectiveness of Green LEDs and Electric Deterrents varied by species, with some species showing deterrence and others exhibiting attraction. In addition, the study used off-the-shelf-deterrent devices not specifically designed for gillnet fisheries, and the study design did not allow for testing optimal configurations of the devices on gillnets. To refine their application, future research should focus on assessing whether alternate devices or modifications, such as adjusting LED wavelength or brightness, refining the pulse strength and frequency of Electric Deterrents, or changes to configurations, such as the placement on nets or combinations of Green LEDs and Electric Deterrents, can enhance deterrent effects for vulnerable bycatch species while minimising unintended impacts on target species.

3. Evaluate Operational Feasibility and Industry Adoption

Before industry adoption can be considered, further research is needed to determine the practicality and cost-effectiveness of these deterrents in commercial fishing operations. Future trials should include assessments of device durability, ease of integration into existing fishing practices, and potential impacts on fishing efficiency. Fishers should be involved in refining attachment methods to ensure deterrents are robust, easy to maintain, and do not interfere with net handling or retrieval. Additionally, economic analyses should examine the costs associated with purchasing and maintaining these devices, potential changes in target species catch rates, and the role of financial incentives to support early adopters.

4. Enhance Collaboration Between Researchers, Industry, and Fisheries Managers

Continued collaboration between researchers, commercial fishers, and fisheries managers is critical to ensure that future research is both scientifically rigorous and practically relevant. A co-design approach, where fishers actively participate in the refinement of deterrent technologies and their testing, will improve the likelihood of meaningful results and industry buy-in. Securing funding for industry-driven trials will allow commercial fishers to test deterrents under real-world conditions, providing valuable insights into their practicality and refining best-practice recommendations.

Alternative Gears

To support a successful transition away from gillnets in the NT Barramundi Fishery, the following actions are recommended:

- **Regulatory and policy clarity**: Fisheries managers need to clarify legislative and policy requirements for NT Barramundi Fishery's transition away from gillnets, ensuring regulatory pathways are established for adopting new fishing methods.
- **Pilot trials and field testing**: Conduct targeted pilot trials of the most promising alternative gears (pound nets, tunnel nets, and fish pots) in collaboration with industry. Trials should assess catch efficiency, species selectivity, threatened species interactions and mitigation, commercial viability, and social acceptability..
- **Exploration of emerging fishing technologies**: Support further exploration of innovative gears and technologies such as marine electrofishing, improved trap designs, and bycatch reduction innovations.
- **Sustainable use of gillnets**: Recognise that gillnets will continue to be used during the transition, and interim efforts focusing on ensuring best practices for sustainability and reducing TEPS interactions should be implemented, including reduced soak times, increased net attendance, and mandatory electronic monitoring.

Conclusions

This project explored strategies for reducing bycatch of threatened species in northern Australian gillnet fisheries while maintaining sustainable target species harvests. By testing bycatch mitigation devices and assessing alternative fishing gears, the project generated preliminary insights to inform industry and management decisions. While the bycatch mitigation device trials produced varied results, they provided important baseline data on the potential effectiveness of the devices in gillnet fisheries. However, the findings indicate that these devices require further refinement and validation before they can be considered suitable for implementation. The assessment of alternative gears reinforced the need for industry engagement, regulatory clarity, and structured gear trials to support a transition away from gillnets. Together, these components address the project's primary objectives by identifying challenges and opportunities for reducing interactions with threatened species while maintaining viable fisheries. The findings highlight the need for continued research, adaptive management, and collaborative efforts between industry and regulators to develop effective bycatch mitigation strategies and sustainable fishing practices.

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