FRDC
FISHERIES RESEARCH AND DEVELOPMENT CORPORATION

Improving the effectiveness, efficiency and safety of mitigation tools for protected species interactions in the Eastern Tuna and Billfish fishery

David Ellis, Phil Ravanello and Kate Bevitt

June 2026

FRDC Project No 2020/041

ISBN **979-8-89704-814-4**

Improving the effectiveness, efficiency and safety of mitigation tools for protected species interactions in the Eastern Tuna and Billfish fishery
FRDC 2020-041
2025

Ownership of Intellectual property rights

Creative Commons licence

Disclaimer

Researcher Contact Details

Name:	David Ellis
Address:	15/27 Giles St KINGSTON 2604 ACT
Phone:	0427 837 966
Fax:	
Email:	ceo@tunaaustralia.org.au

FRDC Contact Details

Address:	25 Geils Court Deakin ACT 2600
Phone:	02 6122 2100
Email:	frdc@frdc.com.au
Web:	www.frdc.com.au

Foreword

Tuna Australia represents statutory fishing right holders, fishing businesses, processors and associated members across Australia's Eastern and Western tuna and billfish fisheries. Our purpose is to strengthen representation of the industry while supporting ecological sustainability, economic resilience and critically, the safety and wellbeing of the people who work within it.

Ensuring that people are safe at work is of paramount importance to Tuna Australia and is fundamental to the objectives and values of our association. Commercial fishing is an inherently high-risk occupation, and measures introduced to achieve environmental outcomes must not inadvertently create new or unacceptable risks for crews. This project was undertaken to address that challenge directly.

One of the key conservation challenges facing the ETBF longline fishery is managing interactions with endangered, threatened and protected species, including seabirds, marine turtles, sharks and marine mammals, all of which are protected under the Environment Protection and Biodiversity Conservation Act 1999. The aim of FRDC Project 2020-041 was to improve the effectiveness and efficiency of protected species mitigation tools used in longline fisheries, while explicitly addressing the need to protect crew safety. Since the introduction of protected species mitigation requirements more than 25 years ago, injuries associated with flyback events and on-deck interactions have been an ongoing and recognised risk for longline crews. This project was undertaken to respond to that legacy issue by combining field trials, engineering assessment and the development of a dedicated flyback simulation system to better understand how mitigation tools perform under real operating conditions, how risks to crew arise, and how those risks can be reduced without undermining conservation outcomes.

This research is important because protected species mitigation is a necessary component of responsible fishing, yet poorly designed or poorly understood mitigation measures can increase the risk of serious injury through flyback events and on-deck hazards. Addressing this risk is essential not only for the wellbeing of fishers, but also for maintaining confidence in mitigation requirements, supporting compliance and ensuring conservation outcomes are durable.

The primary beneficiaries of this research are the fishers and crews who work on longline vessels, along with fishing businesses seeking practical and safe mitigation solutions. Fisheries managers, regulators and certification bodies also benefit from an improved evidence base that integrates conservation performance with work health and safety considerations. Beyond Australia, the findings are relevant to international fisheries and regional fisheries management organisations facing similar challenges, and the project has already generated interest and engagement at regional and global forums.

Key findings from the project demonstrate that effective protective species mitigation, operational practicality and crew safety can be achieved together.

The research shows that certain gear configurations and design features can significantly influence flyback risk, and that mitigation tools can be refined or adapted to reduce injury risk without undermining conservation effectiveness. Importantly, the project provides practical, tested options that can be adopted by industry.

As a result of this work, fishers, managers and policy makers should approach protected species mitigation as a system that must account for safety, effectiveness and real-world deployment, rather than focusing on single tools in isolation.

The project highlights the importance of outcome-based mitigation, informed by evidence and supported by appropriate extension, rather than prescriptive approaches that may have unintended consequences.

The outcomes of this project may have application well beyond the Australian tuna fishery. Through the development of engineered mitigation devices, a refined flyback simulation model and a comprehensive extension package, the project has strengthened industry capability, informed policy and contributed to international discussions on safe and effective seabird mitigation. These outcomes will continue to be applied and extended well after the formal completion of the project.

This project represents a collaborative approach to improving mitigation measures for protected species interactions, with a particular focus on seabirds, while enhancing work health and safety outcomes for crew. The findings highlight the importance of integrating mitigation performance and operational safety within commercial fishing environments.

Contents

Tables

Figures

Acknowledgments

This project would not have been possible without the generous support, expertise and commitment of a wide range of stakeholders involved across its many components. Tuna Australia sincerely thanks the following individuals and organisations for their valuable contributions.

Industry

The project was fundamentally driven by industry identified work health and safety concerns, and nearly all Tuna Australia members contributed in some form. Many companies provided advice, shared operational insights, or made vessels available for equipment trials. The Tuna Australia Board ensured the project remained grounded in industry needs throughout its delivery. We are particularly grateful to the Fishing Masters who participated in trials and contributed to the development of extension and adoption materials that will support uptake of project outcomes. Special thanks are extended to Mr Pavo Walker and Mr John Skoljarev for their innovative thinking and practical input that helped shape key elements of the research. Further, we appreciate financial management of the project by Addition Accounting.

Fisheries Research and Development Corporation (FRDC)

We gratefully acknowledge the support of the FRDC, and in particular, Dr Patrick Hone and Dr Toby Piddocke, for enabling this work through funding support, project extensions and ongoing administrative guidance throughout the life of the project.

Australian Fisheries Management Authority (AFMA)

We thank AFMA and several current and former AFMA staff for their contributions to project governance and design, assistance with funding arrangements, provision of advice, processing of scientific permits and access to relevant data. AFMA's additional financial support for project equipment and consumables was particularly important in ensuring continuity of project delivery.

Project Steering Committee and governance

A project steering committee was established to provide oversight, expert advice and guidance on project planning, budget management and strategic direction. The steering committee comprised representatives from industry, government, an environmental non-government organisation and an independent fisheries consultant.

The initial steering committee included Dr Nick Rayns (Future Fish Consulting), Mr David Ellis and Mr Phil Ravanello (Tuna Australia), and representatives from AFMA. Due to organisational changes over the course of the project, several senior AFMA staff rotated through the committee role. Dr Nick Rayns is especially acknowledged for his role in managing early stakeholder engagement and acting as a key liaison between FRDC and the project team during the project establishment phase.

Mr Nigel Brothers (Humane Society International) provided expert seabird mitigation advice to the steering committee. Humane Society International initially offered financial assistance to support a proposed trial of the Underwater Bait Setter.

However, this support was later withdrawn due to concerns regarding the use of live bait in research proposals. Notwithstanding this, the early technical guidance provided was valuable to project design.

The steering committee also considered linkages with companion project FRDC 2021-078, ensuring that this WHS-focused mitigation project was complementary and, where appropriate, aligned with broader mitigation research outcomes. Several concepts originally discussed under FRDC 2020-041 were subsequently incorporated into FRDC 2021-078 where they related more directly to operational performance rather than safety. Three mitigation approaches, shortened safety leads, Hookpod Mini and Procella hook variants were assessed against industry-standard gear across testing environments in both projects.

Australian Maritime College (AMC) Underwater Collision Research Facility

We acknowledge the Australian Maritime College Underwater Collision Research Facility, led by Dr Roberto Ojeda, for providing world-class facilities, technical expertise and analytical support that were critical to the success of the controlled flyback simulations and adaptive tori line evaluations.

Research and technical contributors

We thank Dr Clara Obregon for her work collating and analysing data relating to tori lines and shortened safety leads. We also acknowledge Fish International for their support in designing and manufacturing shortened safety leads, constructing tori lines, and sourcing materials for testing and deployment.

Broader stakeholder engagement

We also acknowledge the broader seabird conservation and research community for their interest and engagement with the project. This included participation by Australian Antarctic Division staff in flyback simulations, industry workshops and presentations, and promotion of project findings through regional advisory and management forums.

Reviewer contributions

The authors acknowledge the valuable contributions of the independent reviewers who provided detailed technical and scientific feedback on the draft report. Their comments challenged assumptions, improved the presentation and interpretation of results, strengthened the discussion of limitations and helped ensure the report reflects both operational experience and scientific rigour. While the final interpretations and conclusions remain those of the authors, the constructive engagement of reviewers significantly enhanced the quality and robustness of the final document.

Abbreviations

ACAP	Agreement of the Conservation of Albatross and Petrels
AFMA	Australian Fisheries Management Authority
AMC	Australian Maritime College
AMC Search	Australian Maritime College commercial services
DBL	Double-weighted Branchline Leader
EEZ	Exclusive Economic Zone
ETBF	Eastern Tuna and Billfish Fishery
ETP	Endangered, Threatened, and Protected species
FRDC	Fisheries Research and Development Corporation
HLA	Hawaii Longline Association
HSI	Humane Society International
IOTC	Indian Ocean Tuna Commission
PPE	Personal Protective Equipment
RFMO	Regional Fisheries Management Organisation
STAP	Seabird Threat Abatement Plan
STH	Smart Tuna Hook
STM	Striped marlin
TA	Tuna Australia
TAP	Threat Abatement Plan
UBS	Underwater Bait Setter
UCRF	Underwater Collision Research Facility
UniSC	University of the Sunshine Coast
WCPFC	Western Central Pacific Fisheries Commission
WCPO	Western Central Pacific Ocean
WHS	Work Health and Safety
WTBF	Western Tuna and Billfish Fishery

Executive Summary

This report presents the outcomes of assessing protected species mitigation in Australian tuna longline fisheries with the aim of protecting fishing crew safety. The project was undertaken in the Eastern Tuna and Billfish Fishery between 2020 and 2025 in response to long-standing concerns that some mitigation measures, while environmentally necessary, can increase the risk of crew injury through flyback events on fishing vessels. Using field trials, engineering assessment and controlled flyback simulations that replicate the physical forces and conditions experienced on board fishing vessels, the project tested how mitigation tools perform in real fishing operations and how risks to people can be reduced without compromising protected species protection.

Background

Protected species mitigation measures have been progressively implemented in Australian longline fisheries over several decades to reduce interactions with species groups including seabirds, turtles and sharks. These measures have typically been developed to address specific conservation risks for individual species groups.

When applied in combination under operational fishing conditions, these measures can alter the mechanical behaviour of fishing gear, particularly in relation to line tension, failure dynamics and recoil behaviour. Industry experience has identified that these interaction effects can contribute to flyback events and associated injury risk, although these risks have not been systematically assessed alongside mitigation effectiveness.

This project was undertaken to address this gap by evaluating protected species mitigation measures and work health and safety outcomes as part of an integrated system, ensuring that conservation objectives can be achieved in a manner that is practical, effective and safe for crew.

Aims and objectives

The project aimed to improve the effectiveness and efficiency of protected species mitigation tools used in longline fisheries while ensuring those tools do not compromise crew safety and operational practicality. Specific objectives included understanding how flyback risk arises, assessing how gear design and configuration influence injury risk, and identifying practical mitigation approaches that reduce risk to both protected species and people. A further objective was to generate evidence to support industry practice and management decision-making.

Methodology

To address our aims and objectives we combined at-sea field trials on commercial fishing vessels with engineering assessment and controlled simulation testing. A dedicated flyback simulation model was developed and refined to allow repeatable testing of flyback behaviour under different gear configurations. This approach enabled safety risks to be assessed in a manner that would not be feasible, robust, or safe through at-sea trials alone. However, this approach ensured findings remained grounded in real fishing operations.

Results and key findings

Our research found that flyback risk is strongly influenced by gear design and configuration, including line weighting, safety leads and branchline construction. Some mitigation approaches can increase injury risk if safety is not explicitly considered. The research demonstrated that mitigation effectiveness and crew safety can be improved together through refined gear configurations, engineering-based safety devices and practical design changes that do not reduce protected species mitigation performance.

While international best-practice guidance, including that developed by the Agreement on the Conservation of Albatrosses and Petrels, provides an essential foundation for seabird mitigation, the project found that approved or endorsed mitigation methods are not always fit for purpose across all fishing contexts. Longline operations vary considerably by region, vessel design, gear configuration and environmental conditions. As a result, effective and safe mitigation often requires tools that can be configured and adapted by fishers to suit complex, real-world operating conditions, rather than reliance on narrowly prescribed applications.

Implications for relevant stakeholders

This research demonstrated that fishers and fishing businesses now have access to practical, tested mitigation options that improve safety without disrupting operations. These outcomes support workforce wellbeing, business continuity and the social sustainability of fishing communities.

The project provides evidence that protected species mitigation should be assessed as an integrated system that considers safety, effectiveness and real-world use, rather than focusing on single tools in isolation. The findings are also relevant to certification bodies and international fisheries facing similar safety and conservation challenges.

Recommendations

Future protected species mitigation guidance and requirements should explicitly consider crew safety alongside conservation outcomes. Further research and testing using simulation-based approaches is recommended to assess new mitigation tools before widespread adoption.

Keywords

Protected species mitigation; crew safety; flyback risk; longline fishing; tuna fisheries; seabirds; work health and safety; gear design

1. Introduction

Australian tuna fisheries comprise the Eastern and Western Tuna and Billfish Fisheries (ETBF and WTBF), the Southern Bluefin Tuna fishery (SBTF) and the Eastern and Western Skipjack Fisheries (**Figure 1.1**)

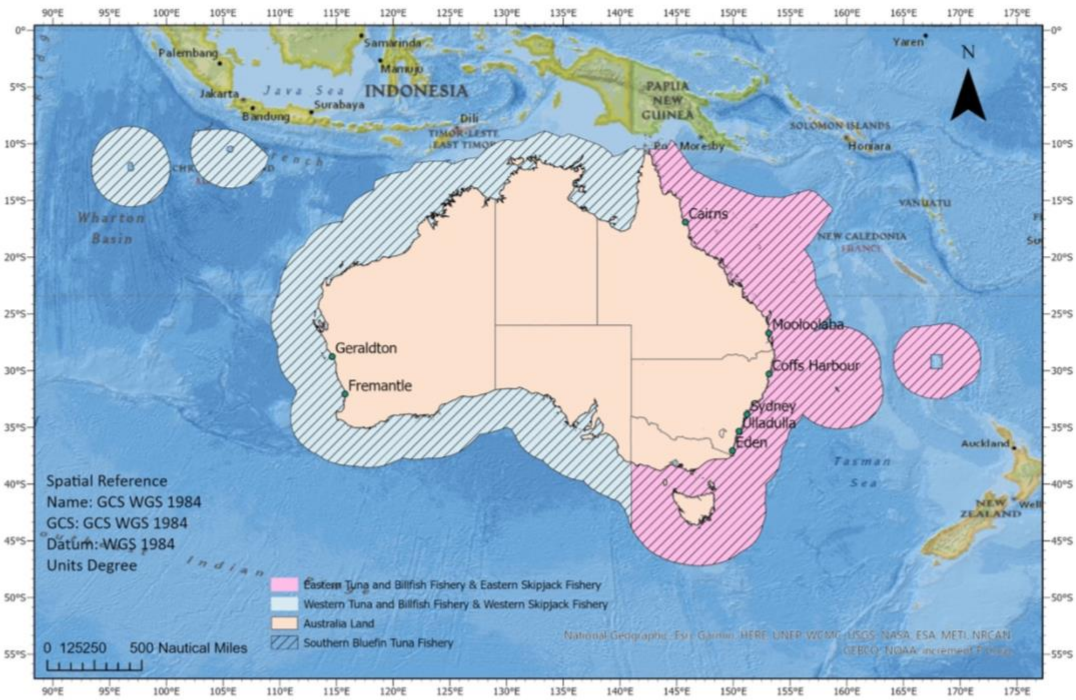


Figure 1.1 Map of Australian tuna fisheries showing management zones and spatial extent of the Eastern Tuna and Billfish Fishery (ETBF) and Western Tuna and Billfish Fishery (WTBF). Image provided by the Australian Fisheries Management Authority.

Of particular interest to this research is Australia's longline tuna fishing sectors. The ETBF spans the eastern half of Australia's Exclusive Economic Zone (EEZ), from Cape York to the Victoria–South Australia border, while the WTBF occupies the majority of EEZ area, from the South Australia/Victoria border stretching west around Western Australia and Northern Territory coastlines to the tip of Cape York, Queensland (**Figure 1.1**). Longlining and minor line (i.e. trolling, poling, rod and reel) are the fishing methods used in these fisheries. However, this research focuses on the longline sector of the ETBF that targets yellowfin tuna (*Thunnus albacares*), bigeye tuna *(T. obesus*), albacore tuna (*T. alalunga*), southern bluefin tuna (*T. maccoyii*), broadbill swordfish (BBS) (*Xiphias gladius*) and striped marlin (*Tetrapturus audax*). ETBF longline fishing operations are conducted from a wide range of ports, including Cairns, Bundaberg, Mackay, Mooloolaba, the Gold Coast, Coffs Harbour, Tuncurry, Yamba, Nelson Bay, Sydney, Ulladulla, Narooma, Bermagui, Eden and Hobart.

Longline fishing gear used in the Australian longline fishery is designed to operate over large spatial scales and depths with mainlines extending up to 100 km that carry thousands of hooks that can cover depths from the surface to around 300 m. Despite best practice operational controls, longlines can unintentionally and indiscriminately interact with protected species that share similar habitats as the target species in the marine environment. While fishers aim to avoid protected species interactions wherever possible, fishing gear inevitably interacts with endangered, threatened, and protected (ETP) species such as seabirds, marine mammals, sea turtles, and sharks. The ETBF and WTBF mandate a comprehensive suite of mitigation measures for longline, including line weighting, tori lines, handling and release protocols, and spatial and temporal management. These measures have significantly reduced interaction rates over time (Brothers et al., 2010; AFMA, 2011; Zhou et al., 2020). However, residual interactions and mortalities persist, reflecting the inherent challenges of fishing in open ocean ecosystems. Importantly, some mitigation techniques, while partially effective in reducing protected species interactions, have introduced new risks to crew safety, with documented injuries associated with weighted lines, flyback events, and mitigation gear deployment (Pierre et al., 2015; ACAP, 2019). At the same time, there is increasing scrutiny from environmental organisations and sustainability certification schemes on further minimising protected species interactions and improving outcomes for ETP species. In this context, refining mitigation techniques to materially improve fisher safety while enhancing effectiveness, reduce operational and cost burdens, is of paramount importance. Continued innovation is therefore essential to ensure fisheries can meet evolving sustainability expectations and responsibilities, uphold their role as stewards of the ocean, and protect and enhance the marine estate for generations to come.

Aside from the introduction of circle hooks to reduce turtle interactions, the replacement of wire trace with monofilament leaders to reduce shark mortality, and the adoption of line weighting and tori line systems to reduce seabird interactions, this project focuses on the cumulative work health and safety consequences arising from regulated protected species mitigation measures. While each measure was introduced to address a specific protected species interaction, their combined application has fundamentally altered branchline behaviour, operational practices and crew risk profiles within commercial longline fisheries.

1.1 Seabird bycatch context

Incidental capture in longline fisheries is recognised as the single greatest global threat to seabirds, with an estimated 160 000–320 000 birds killed annually (Anderson et al. 2011; Zhou et al. 2021). Species groups most at risk include albatrosses, petrels and shearwaters, (Zhou et al. 2021; Jiménez & Barrington 2021), with interactions occurring primarily during line setting and, to a lesser extent, hauling when baited hooks remain accessible near the surface (Brothers et al. 2010; Løkkeborg, 2011). As a result, pelagic longline fisheries have been a long-standing focus of international conservation concern for seabirds.

In Australian waters, pelagic longline fishing was listed as a key threatening process to seabirds under the *Endangered Species Protection Act 1992*, leading to the development of a national Threat Abatement Plan (TAP) for reducing incidental seabird catch in pelagic longline operations in 1998. The TAP established a performance objective of reducing seabird captures to below 0.05 birds per 1000 hooks, and early mitigation regulations focused on operational controls such as night setting and the mandatory carriage of tori lines for vessels operating south of 30°S. While these measures represented an important early response, residual bycatch persisted and operational limitations associated with night setting became apparent.

In pelagic longline fisheries, a typical set operation may take 5–6 hours to deploy, while hauling can take between 5–10 hours depending on hook numbers, catch rates and operational conditions. Effective fishing operations are generally structured around evening and morning feeding periods, requiring gear deployment prior to the evening bite and hauling following the morning bite. This operational pattern also supports crew rest and fatigue management requirements.

Restricting setting activity to periods after nautical dusk can significantly reduce operational flexibility. To maintain access to both feeding periods under strict night-setting requirements, gear may need to remain in the water for extended periods, increasing the likelihood of product quality deterioration, shark depredation and mortality of non-target species retained on the line. Longer soak times may also reduce opportunities to release species alive and can constrain the ability to undertake subsequent fishing operations within the same operational cycle.

In response to persisting residual bycatch, the Australian Fisheries Management Authority (AFMA) facilitated a series of industry-initiated seabird mitigation trials between 2001 and 2004, evaluating a range of mitigation tools including underwater setting devices, tori lines and various line-weighting regimes, with the aim of reducing seabird interactions during daytime longline operations (Lawrence et al., 2005; Robertson et al., 2010). These trials provided important insights into the factors influencing seabird interactions and informed subsequent research, policy development and management arrangements, although early mitigation measures did not consistently achieve the TAP performance target across all areas of the fishery. In particular, mitigation performance varied between operational areas and environmental conditions, with higher interaction rates generally occurring in southern areas of the fishery where seabird abundance and competition for baited hooks were greatest. The effectiveness of early mitigation measures was also influenced by sink rate performance, wind and sea state, vessel configuration and variability in operational deployment. Differences in vessel size, deck layout, line shooter arrangement, setting height and gear handling practices influenced how mitigation measures performed in practice, meaning that standardised mitigation requirements did not always produce consistent operational outcomes across the fleet.

Seabird bycatch mitigation is now guided by a complex suite of international, regional and domestic frameworks, reflecting the long-standing conservation concern associated with longline fisheries (FAO 1999; Brothers et al. 2010).

These include global instruments such as the United Nations Food and Agriculture Organization's *International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries* (FAO 1999), multilateral conservation agreements including the *Agreement on the Conservation of Albatrosses and Petrels* (ACAP 2004), and national policy instruments such as Australia's *Seabird Threat Abatement Plan* (Environment Australia 1998; DCCEEW 2022). Regional fisheries management organisations have incorporated seabird conservation and bycatch mitigation measures that are implemented through domestic fisheries legislation, management plans, permit conditions and fishery-specific management arrangements (ICCAT 2007; CCSBT 2011; IATTC 2011; WCPFC 2018; IOTC 2019). While these frameworks have been instrumental in driving awareness, accountability and improved environmental performance, their cumulative effect has been the proliferation of overlapping initiatives, guidance materials and policy expectations. In practice, effective seabird mitigation ultimately depends on the consistent, practical and safe application of a small number of proven tools that are fit for purpose within specific fisheries, environmental conditions and vessel configurations.

In Australia, the implementation of mitigation measures such as tori lines and line-weighting has been associated with a substantial reduction in seabird interactions, declining from an estimated ~8 000 reported interactions annually in the 1990s to fewer than 100 per year in more recent decades, representing less than 0.1 per cent of estimated global longline seabird bycatch (Brothers et al., 2010; AFMA 2011; Zhou et al., 2020). This experience highlights the importance of focusing on refining and improving the effectiveness of core mitigation techniques, while ensuring sufficient operational flexibility for their application under different fishing conditions and vessel configurations. Rather than relying solely on increasingly prescriptive policy settings, effective mitigation outcomes are more likely to be achieved through adaptive, performance-based approaches that allow operators to apply appropriate mitigation tools in a manner consistent with both conservation objectives and work health and safety considerations. Policy refinement may still be required as new information and operational experience emerge through ongoing mitigation development and application.

1.2 **Shark interaction mitigation context**

Shark interactions have long been recognised as a significant operational and conservation issue within pelagic longline fisheries. Historically, wire trace leaders were commonly used to increase the retention of target fish, and in particular, preventing sharks from biting through the leader and escaping following capture (Ward et al. 2008; D'Alberto et al. 2024).

In response to increasing international and domestic conservation concerns regarding shark mortality, a range of fisheries progressively transitioned from wire trace leaders to monofilament branchline leaders during the 2000s and 2010s. Within Australian pelagic longline fisheries, the replacement of wire trace with monofilament leaders became an important mitigation measure to reduce shark retention and improve post-release survival outcomes for a range of shark species (Ward et al. 2008; Patterson et al., 2014).

While highly effective in reducing shark mortality, the transition to monofilament leaders altered the mechanical behaviour of branchline systems. Unlike wire trace, monofilament leaders are susceptible to bite-offs when sharks interact with hooked fish or bait. Under tension, these bite-offs can result in sudden release of stored energy within the branchline system and contribute to flyback events, particularly where weighted components are incorporated into the gear configuration. Consequently, shark mitigation measures have become an important consideration in the broader assessment of work health and safety risks associated with modern longline fishing operations.

1.3 Turtle interaction mitigation context

Incidental capture of marine turtles in pelagic longline fisheries has also been the focus of substantial international research and management attention. During the late 1990s and early 2000s, a growing body of research demonstrated that traditional J-hooks were associated with higher rates of deep-hooking and increased injury to turtles compared with alternative hook designs (Watson et al. 2005; Gilman et al. 2006; Read 2007), with subsequent studies further evaluating the effectiveness of circle hooks across different fisheries and operational contexts (Cambiè et al. 2012).

As a result, many pelagic longline fisheries progressively adopted circle hooks, often in combination with changes to bait type and handling procedures, to reduce turtle injury and improve post-release survival. Within Australian longline fisheries, circle hooks became widely adopted as both a conservation measure and a practical operational tool capable of reducing turtle impacts while maintaining target species catch rates (Watson et al., 2005; Gilman et al., 2006; Gilman et al., 2007).

However, circle hooks also influence the dynamics of branchline loading and release. Unlike traditional J-hooks, circle hooks are designed to rotate and lodge in the jaw or mouth of the captured animal, altering hook retention characteristics and the circumstances under which hooks may tear free under tension. Combined with line weighting and monofilament leaders, these changes have contributed to altered flyback pathways and recoil behaviour within modern branchline systems.

1.4 Evolution of protected species mitigation measures

Over the past three decades, Australian pelagic longline fisheries have progressively implemented a range of mitigation measures to reduce interactions with protected species. The introduction of monofilament leaders in place of wire trace has substantially reduced shark retention and mortality, while the adoption of circle hooks has contributed to reductions in turtle hooking rates and improvements in post-release survival. Similarly, the introduction of line weighting and tori line systems has played a significant role in reducing seabird interactions and mortality.

Collectively, these measures represent major conservation achievements and demonstrate the fishing industry's capacity to adapt fishing practices in response to emerging environmental and conservation challenges. While each mitigation measure was developed to address a specific protected species interaction, their combined implementation has fundamentally altered branchline dynamics, gear behaviour and operational fishing practices within pelagic longline fisheries.

Historically, protected species mitigation measures have been evaluated primarily on the basis of their conservation performance and ability to reduce interactions with protected species. Comparatively less attention has been given to the cumulative operational and work health and safety consequences arising from the interaction of multiple mitigation measures within the same fishing system. As fisheries management continues to evolve, there is increasing recognition that protected species mitigation measures should be considered as integrated operational systems that account not only for conservation outcomes, but also for operational practicality, effectiveness and crew safety.

This broader context provides the foundation for examining the work health and safety implications associated with modern branchline mitigation systems.

1.5 Work Health and Safety context

Commercial fishing is consistently recognised as one of Australia's highest-risk occupations, with longline fishing operations exposing crew to a range of mechanical, environmental and operational hazards. Within pelagic longline fisheries, flyback events involving tensioned branchline systems are widely regarded by fishers as one of the most serious work health and safety risks encountered during routine fishing operations.

Flyback events occur when hooks, leaders or other terminal gear fail under tension, causing stored energy within the branchline system to be rapidly released. This can result in hooks, swivels and weighted components recoiling towards crew at high velocity. Such events have caused serious injuries, including fractures (**Figure 1.2**), puncture wounds, permanent vision loss and fatalities internationally (McCormack & Papworth, 2014; ACAP, 2019).

Although severe incidents are documented, flyback events are widely considered to be under-reported, with many near misses and minor injuries not formally recorded (Pierre et al., 2015; ACAP, 2019).

Figure 1.2 Example of a severe injury resulting from a flyback event during longline operations, illustrating the potential impact of recoiling weighted gear on crew safety.

Physical evidence of repeated flyback impacts is commonly observed on vessels, including damage below the gunwale in areas where weighted swivels and hooks recoil during hauling (**Figure 1.3**).

Figure 1.3 Structural damage observed below the gunwale of a tuna longline vessel (blue area) caused by repeated flyback impacts from recoiling weighted gear during hauling operations.

Additional risks arise from the interaction between protected species mitigation measures and fishing gear during normal fishing operations. Entanglement of the mainline with tori lines, particularly where poorly engineered weak links or release clips are fitted, can result in sudden release of tensioned gear and high-energy recoil events towards the stern of vessels. These events are difficult to predict and may occur during routine setting operations, increasing the exposure of crew working in close proximity.

These interaction effects demonstrate that protected species mitigation measures cannot be assessed in isolation, as changes intended to improve outcomes for one species group may influence operational safety and gear behaviour elsewhere within the system.

Flyback injuries associated with longline fishing have been documented internationally and domestically (Brothers et al. 2010; Rawlinson & McCormack 2016). Despite the seriousness of these outcomes, crew safety considerations were not explicitly integrated into the early design of protected species mitigation frameworks. As mitigation requirements have expanded and operational complexity has increased, there is a growing need to systematically assess the interaction between mitigation effectiveness, gear behaviour and crew safety.

In response, this study investigates design principles that seek to maintain effective protected species deterrence while reducing work health and safety risks during longline operations. The study focuses on how mitigation measures interact within the branchline system, including the influence of weighting configuration, hook design, leader material and gear handling characteristics on recoil behaviour and operational safety (Rawlinson & McCormack, 2016).

Emphasis is placed on mitigation approaches that reduce the likelihood and consequence of flyback events, promote predictable and stable gear behaviour during deployment and retrieval, and improve operational practicality across different vessel configurations and fishing conditions. Consideration is also given to configurations that minimise tangling, instability and uncontrolled recoil behaviour, supporting safer crew interactions and more consistent operational uptake (Pierre et al., 2015; ACAP, 2019).

These principles provide the framework for the development and evaluation of alternative mitigation designs examined in this study, ensuring that protected species conservation objectives are pursued alongside practical and safe fishing operations.

1.6 Project Rationale

This project (FRDC 2020-041) addresses two closely linked priorities for Australia's tuna longline fisheries: improving crew safety and further refining seabird mitigation performance. Over the past two decades, the ETBF has achieved a substantial reduction in reported seabird interactions following the progressive implementation of mitigation measures and operational changes (Commonwealth of Australia, 2018). Despite this progress, Australia continues to pursue the long-term objective of zero seabird mortalities, as mentioned in the national Seabird Threat Abatement Plan developed within the Australian Government environment portfolio and administered by the Australian Antarctic Division (Commonwealth of Australia, 2018). AFMA gives effect to this policy through the operational management of Commonwealth fisheries requiring the ongoing refinement of mitigation approaches and the evaluation of emerging technologies.

At the same time, the operational changes required to achieve improved seabird outcomes have altered the WHS risk profile of longline fishing operations. Flyback events associated with weighted branchlines now represent one of the most serious occupational hazards faced by crews, with increasing weight mass and proximity to hooks heightening both the frequency and severity of potential injuries.

While existing mitigation tools have delivered important conservation outcomes, many were not designed with crew safety as an explicit consideration. Fishers also report operational inefficiencies associated with some mitigation measures, including increased gear handling complexity, higher rates of tangling, and impacts on fishing efficiency. These factors highlight the need to move beyond incremental adjustments and systematically evaluate mitigation tools through an integrated safety, performance and practicality framework.

This project is complemented by a companion study (FRDC 2021-078), which examines the oceanographic drivers of interactions with endangered, threatened and protected species and compares sink rates across alternative weighting regimes. Together, the projects aim to deliver integrated, industry-ready solutions that improve crew safety, maintain or enhance mitigation effectiveness, and support efficient fishing operations.

The outcomes are expected to be directly transferable to tuna longline fleets internationally and to inform future domestic management, RFMO deliberations and ACAP best-practice guidance.

1.7 Project Aims

The overarching aim of this project is to improve the safety, effectiveness and practicality of seabird mitigation in Australia's tuna longline fisheries while maintaining strong conservation outcomes. To achieve this, the project will pursue the following specific objectives:

1. Quantify work health and safety performance

The project will assess conventional and novel branch-line configurations using controlled flyback simulations to quantify recoil velocity, impact energy and associated injury risk under representative operating conditions.

2. Assess key mitigation devices and practices

The project aims to review existing protected species mitigation practices, including line-weighting options and tori line designs, with a focus on deployability, durability, effectiveness and implications for crew safety.

3. Evaluate alternative mitigation technologies

Emerging mitigation technologies, including weighted hooks, sliding or "safety" weights, hook shields, hook pods, magnesium banding and an underwater bait setter, will be evaluated for their sink-rate performance, safety benefits, operational efficiency and effects on catch performance under Australian fishing conditions.

4. Prototype physical protection systems

Where gear-based solutions are impractical or insufficient, the project will explore the feasibility of physical deflection or barrier systems designed to redirect flyback trajectories away from crew and reduce impact energy, including proof-of-concept testing.

5. Develop industry extension and guidance material

The project will deliver a suite of practical extension materials to support industry uptake of proven solutions and to inform future domestic regulatory settings, RFMO deliberations and best-practice guidance.

In pursuing these aims, the project will explicitly consider operational efficiency alongside safety and conservation outcomes. Fishers have reported that increased line weighting can suppress catch rates by limiting bait movement, while some existing tori line designs are prone to tangling and are difficult to deploy and stow safely. Emerging options, such as sliding "safety leads", weighted hooks (including Procella designs), Hookpod Mini devices and double-weight branch-line configurations, warrant rigorous and comparative assessment of their performance, safety and practicality under Australian conditions.

Where modifications to fishing gear alone cannot adequately address risk, physical deflection or shielding systems may provide a complementary layer of protection, subject to demonstrated effectiveness and operational feasibility.

By integrating engineering analysis, behavioural observation and oceanographic understanding, this project seeks to safeguard fishing crews while sustaining Australia's leading role in protected species conservation. The outcomes will inform domestic fisheries management, RFMO processes and ACAP best-practice advice, reinforcing the ETBF's reputation as an environmentally sustainable, responsible and safe fishery.

1.8 Objectives and Outcomes

1. To trial several new and/or modified protected species mitigation tools and processes in the Eastern Tuna and Billfish Fishery to further reduce the rate of protected species interactions
2. To demonstrate whether new and/or modified mitigation tools and processes are cost-effective and easier to use than the current suite
3. To improve crew safety through revising the design and deployment of protected species mitigation equipment.
4. To provide ETBF vessels with an improved protected species toolkit including better data gathering, greater analysis capability and enhanced information sharing capabilities

A variation to the project was approved on 3 April 2024 to undertake the following research to address objectives 2 and 3. The variations included

5. To assess tori line deployment and storage options. To inform the development of an adaptive tori-line system where lines and materials are tailored to environmental conditions, thereby optimising effectiveness and safety.
6. Conduct additional controlled flyback simulations at the Australian Maritime College (AMC) Underwater Collision Research Facility.
7. Develop a suite of extension products ensuring maximum communications to fishers

2. Methods

To trial several new and/or modified protected species mitigation tools and processes in the Eastern Tuna and Billfish Fishery to further reduce the rate of protected species interactions

2.1 Tori lines

Physical mitigation equipment to reduce seabird interactions with baited hooks is mandatory for all Eastern Tuna and Billfish Fishery (ETBF) longline operators as defined in the ETBF AFMA management arrangements booklet 2025 (AFMA, 2025). Vessels are required to deploy tori lines (**Figure 2.1**) during all daytime sets south of 25°S. For consistency, the term tori line is used throughout this report to describe bird scaring lines. The term tori originates from Japanese longline fisheries and is now widely used internationally to describe bird deterrent lines deployed astern of vessels to reduce seabird interactions with baited hooks. Tori lines consist of a towed backbone fitted with streamer material designed to deter seabirds and reduce access to baited hooks during line setting (**Figure 2.2**)(Brothers et al., 1999). AFMA prescribes a standard tori line design configuration, including streamer length, aerial extent and streamers spaced at 3.5 m intervals (AFMA, 2025).

For clarity and consistency, key gear components and operational terminology used throughout this section are defined below, aligned with AFMA management arrangements.

To support consistent interpretation of terminology used throughout this report, key components of a tori line are described below, aligned with AFMA management arrangements (AFMA, 2025, Attachment D, pp. 59–66).

A tori line comprises the following elements-

Backbone
The main line suspended above the water astern of the vessel, typically extending to achieve an aerial extent of at least 75 m under calm conditions, from which streamers are attached.

Streamers
Single or paired materials attached at intervals along the backbone and hanging down toward the water surface to deter seabirds from accessing baited hooks.

Trailing line or drogue
A section of line or attached object at the terminal end of the backbone that provides drag in the water. This maintains tension in the system, stabilises the tori line and assists in positioning the streamers over the seabird interaction risk area.

Attachment point and tori pole
The point at which the tori line is connected to the vessel, often elevated using a pole or similar structure to increase aerial extent and improve coverage of the baited line during setting.

The aerial extent of a tori line is influenced by the height of the attachment point, the weight and configuration of the streamers, and the drag generated by the trailing line or drogue. In practice, the optimal configuration varies between vessels and operating conditions. The underlying principle is that increasing the height of the attachment point and maintaining tension in the branchline improves aerial extent and coverage of the seabird interaction risk area during line setting.

Tori lines were introduced to the ETBF in 2001 as part of the Seabird Threat Abatement Plan for the incidental catch of seabirds during oceanic longline fishing operations (Commonwealth of Australia, 2001). Since their introduction, the core design and deployment approach has remained largely unchanged and continues to represent the baseline seabird mitigation requirement in the fishery (AFMA, 2025). While tori lines are widely recognised as an effective deterrent for reducing seabird interactions (Brothers et al., 1999; Løkkeborg, 2011), their routine deployment has also highlighted practical operational and work health and safety (WHS) considerations, providing context for the assessment of alternative designs and refinements.

International best-practice guidance for seabird bycatch mitigation in pelagic longline fisheries is provided through the Agreement on the Conservation of Albatrosses and Petrels (ACAP). ACAP recommends tori lines as a primary mitigation measure during line setting, with specifications varying according to vessel size and operational characteristics (ACAP, 2024).

For vessels less than 35 m length overall (LOA), ACAP recommends a minimum aerial extent of 75 m, an attachment height greater than 6 m above sea level, and streamer configurations designed to provide continuous seabird deterrence over the baited line during setting operations. Long streamers should be spaced at intervals of no more than 5 m, while short streamers may be spaced at intervals of no more than 1 m. ACAP also recommends sufficient drag to maintain line stability and minimise lateral movement under crosswind conditions.

For vessels greater than 35 m LOA, ACAP recommends a minimum aerial extent of 100 m, an attachment height greater than 8 m above sea level, and the use of paired tori lines to provide a protected setting corridor over the deployed gear. Streamer spacing should not exceed 5 m, with line design intended to maximise aerial coverage and minimise seabird access to baited hooks during line setting.

ACAP guidance further recognises operational considerations associated with tori line deployment, including tangling risk, drag requirements, vessel configuration and deployment stability under varying environmental conditions (ACAP, 2024). These factors are particularly relevant within the ETBF, where vessel size, deck layout, line shooter arrangement and fishing practices vary considerably across the fleet.

While ACAP guidance provides an important international benchmark for best practice, mitigation effectiveness is influenced not only by prescribed specifications, but also by vessel-specific application, operational conditions and safe integration into fishing operations.

Figure 2.1 Photograph of a deployed tori line astern of a tuna longline vessel in the ETBF during line setting, illustrating typical configuration and aerial extent under operational conditions.

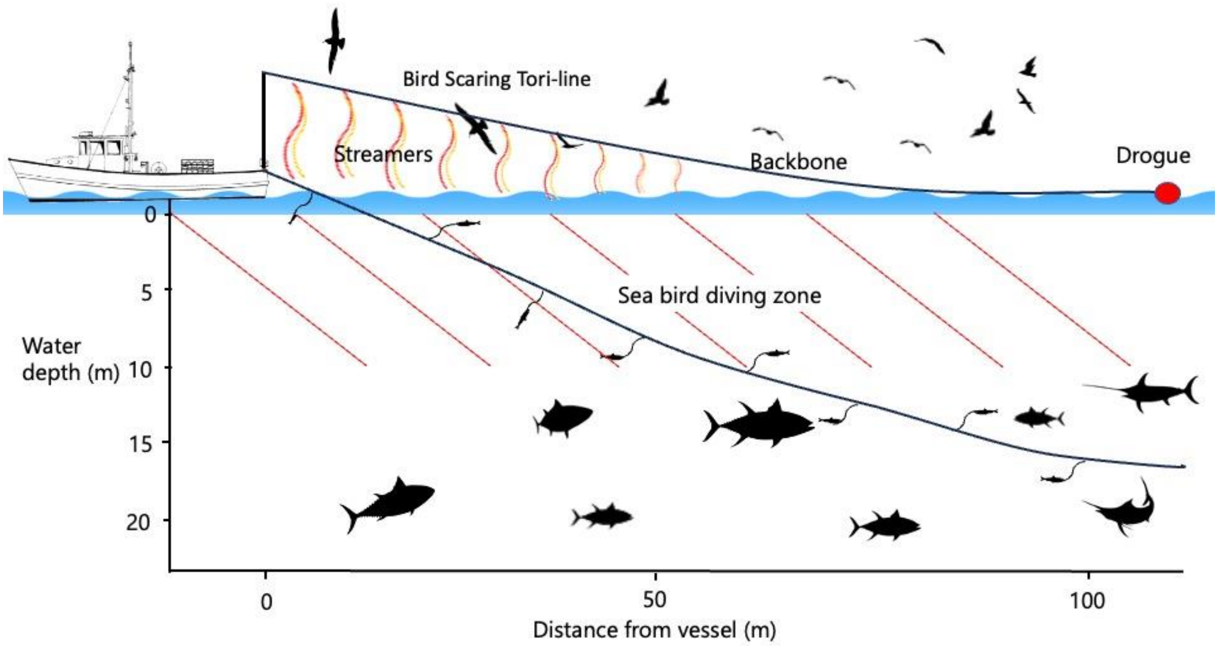


Figure 2.2 Schematic of a tori line deployed astern of a longline vessel, showing the backbone, streamers and trailing line positioned to provide coverage over the seabird interaction risk area during line setting.

2.2 Tori line research

Tori lines are mandatory for all ETBF pelagic longline vessels undertaking daytime setting operations south of 25°S in accordance with AFMA permit conditions and the ETBF Management Arrangements Booklet (AFMA, 2025). At the commencement of this project, AFMA specifications required vessels less than 35 m LOA to deploy a tori line with an overall backbone length of approximately 100 m capable of achieving a minimum aerial extent of 75 m behind the vessel. Streamers are required to be spaced at intervals not exceeding 3.5 m and maintained to remain as close to the water surface as practicable. Vessels were also required to carry a fully constructed spare tori line onboard.

AFMA guidance further described the key functional components of a tori line system, including:

- the backbone;
- streamers;
- drogue/towed drag section; and
- tori pole and attachment point.

The guidance also outlines operational principles influencing aerial extent and deployment stability, including attachment height, backbone weight, drag characteristics, streamer configuration and vessel-specific deployment arrangements (AFMA, 2025).

This project used the AFMA specifications as the baseline reference configuration against which modified and alternative tori line systems were evaluated. The project specifically assessed the influence of alternative backbone materials, streamer materials, attachment systems, streamer spacing, drogue configuration and deployment arrangements on:

- aerial extent;
- deployment stability;
- tangling risk;
- operational practicality;
- and work health and safety considerations.

As the project progressed, findings from vessel trials, fisher feedback and technical assessments contributed to ongoing discussions between Tuna Australia, AFMA and seabird mitigation specialists regarding refinement of tori line guidance and best-practice deployment approaches within the ETBF. This included consideration of alternative materials, detachable streamers, colour coding systems, modified drag arrangements and adaptive configurations suited to differing vessel sizes and operating conditions.

Further details regarding the current AFMA guidance and recommended tori line specifications are provided in Attachment D of the ETBF Management Arrangements Booklet (AFMA, 2025).

This study trialled alternative tori line materials, configurations and construction methods to address practical issues reported by industry, including streamer entanglement, inconsistent aerial extent, deployment handling difficulties and mitigation performance. Tori lines were constructed with streamer spacings of 3.5 m, consistent with current ETBF specifications, and

5 m and 7 m, reflecting international best-practice guidance, using improved materials and construction techniques. These configurations were subjected to comparative field evaluation under normal fishing operations.

2.2.1 Vessel selection and permitting

Participating vessels were selected to reflect the predominant vessel types and operational configurations within the ETBF, including variation in vessel size, layout and gear deployment practices. Selection was based on a combination of representativeness and willingness of owners and skippers to undertake experimental trials under commercial fishing conditions. The same core group of vessels was used across trials where possible, with minor variation due to operational constraints. Data were collected at the level of individual sets across participating vessels and are considered representative of a range of typical fishing practices within the ETBF. Further vessel selection criteria for the trial was based on the following

- Knowledge of the performance of existing tori lines, assessed through an industry-wide survey.
- Vessel selection also considered historical operational performance in relation to seabird interaction reporting and Threat Abatement Plan (TAP) performance metrics (DAWE, 2018). The intent was not to select vessels from a range of operational profiles representative of differing mitigation performance and fishing practices within the ETBF. This approach enabled assessment of mitigation measures across a broader spectrum of operational conditions and interaction risk scenarios.
- Practical ability to accommodate a technical officer onboard for troubleshooting and supplementary data gathering.

Trial effort was concentrated within operational areas where seabird interaction risk was considered highest to maximise the opportunity to assess mitigation performance and operational behaviour under active interaction conditions.

Scientific research permits were issued by AFMA for five vessels from 1 November 2021 to 30 April 2022 (AFMA Permit IDs 2021/R01–R05).

Vessels were based in Ulladulla and Bermagui, New South Wales. One vessel withdrew from the trial due to COVID-19-related crew shortages and mechanical issues.

Results are interpreted as indicative of mitigation performance under operational conditions and are not intended to provide statistically representative estimates at the fleet level.

2.2.2 Behavioural observations and tori line performance assessment

Seabird behaviour and tori line performance were recorded during line setting by participating fishing crew using standardised observational categories developed for this project.

These categories were designed to be practical, repeatable and aligned with normal fishing operations in the ETBF, recognising that observations are undertaken in a dynamic operational environment.

Seabird behaviour categories

Seabird behaviour was classified into the following categories to distinguish between presence and interaction risk:

- Attacking and foraging
  Birds actively attempting to capture bait from hooks or branchlines, including diving, surface seizing or making direct contact with fishing gear. This includes both attempted and successful bait capture and represents the highest level of interaction risk. These categories are consistent with operational observations used to assess seabird presence, behaviour and interaction risk in longline fisheries.
- Flying
  Birds transiting through the area without orienting toward the vessel, fishing gear or baited hooks. Movement is directional, with no circling or repeated passes over the setting area.
- Following boat
  Birds maintaining position astern of the vessel and tracking its movement within the setting area but not actively attempting to locate or access baited hooks.
- Foraging
  Birds actively attempting to locate and access food, including repeated passes over the setting area, increased attention to baited hooks and positioning behaviour consistent with imminent feeding, but without direct contact with gear.
- Searching
  Birds exhibiting exploratory behaviour, including circling, scanning and reorienting flight paths in response to the vessel or gear, indicating awareness of potential feeding opportunities but without focused feeding attempts.

Tori line performance categories

Tori line performance was assessed using qualitative operational categories based on observable deployment characteristics, deployment stability and effectiveness in deterring seabirds from accessing baited hooks during line setting operations.

Performance assessments considered a range of operational observations including:

- aerial extent;
- streamer coverage over baited hooks;
- deployment stability;
- tangling frequency;
- hook-up occurrence;

- ease of deployment; and
- overall seabird deterrence behaviour observed during setting operations.

Within the context of this study, a “hook-up” referred to any event where branchlines, hooks or other fishing gear became entangled with, snagged on, or fouled the tori line or streamer system during line setting operations. Hook-ups and tangling events were recorded as indicators of operational practicality, deployment stability and potential work health and safety risk.

Tori line performance categories were defined as follows:

- Good – Stable deployment with consistent aerial extent and effective streamer coverage over the area of baited hooks, providing effective seabird deterrence with minimal tangling or hook-up events.
- Ok – Moderate performance with some variability in aerial extent, streamer stability or coverage, resulting in partial protection of baited hooks and occasional operational interference or tangling events.
- Poor – Inadequate performance due to limited aerial extent, instability, tangling, hook-ups or insufficient streamer coverage, resulting in increased seabird access to baited hooks and reduced operational effectiveness.

Assessments were undertaken within the context of prevailing operational and environmental conditions, including wind strength, sea state, swell direction, vessel configuration and fishing practices.

Data collection

Participating fishing crew were briefed on the observational categories prior to data collection. Observations were recorded during routine fishing operations and reflect conditions encountered during normal line setting in the ETBF. The use of trained crew to collect observational data is consistent with standard industry-based data collection approaches and enables the capture of operationally relevant information across a broad range of conditions that would not be achievable through dedicated scientific observation alone.

2.2.3 Tori Line A – Modified standard configuration

Tori Line A was constructed in accordance with AFMA’s bycatch mitigation permit conditions (AFMA, 2021). Materials conformed to AFMA specifications, including a monofilament backbone and streamer materials, but with several changes including:

- Adjusted connection points to reduce tangling
- A revised number of streamers per streamer to optimise visual coverage
- A coloured backbone line to assist in streamer alignment and reduce line twist during deployment

2.2.4 Tori Line B – Enhanced material configuration

Tori Line B was constructed using alternate materials that, while familiar to longline fishers, are not commonly applied in tori line construction. These included:

- Sekiyama braid for both the backbone and trailing line for superior durability and reduced memory
- Stiff high-visibility pallet strapping in alternating colours to improve streamer visibility and resilience
- Crane swivels as fixed attachment points for streamers to improve articulation and minimise twist

These materials were selected based on field usability, handling characteristics, and alignment with the ACAP principles of effectiveness, practicality, and cost-efficiency (ACAP, 2021).

2.2.5 Tori Line C – Bespoke detachable configuration

A project extension enabled the development and qualitative evaluation of a third tori line configuration incorporating a 7 m streamer spacing. This configuration extended beyond streamer spacings commonly referenced in international best-practice guidance and was included to assess the influence of reduced structural complexity on aerial extent, line stability and operational handling. The design was informed by expert technical advice from Nigel Brothers (Humane Society International), which emphasised prioritising consistent aerial coverage and stability over increased design complexity. This approach reflects the premise that a stable, streamlined configuration that reliably covers the seabird interaction risk area during line setting may provide effective deterrence without introducing additional handling or safety risks (Brothers, pers. comm., 2024).

Tori Line C - Construction

- A 2 mm Dyneema backbone for strength and low stretch.
- A 200 m trailing mainline, welded and sealed with heat-shrink tubing.
- Colour-coded 10 cm heat-shrink markers at 7 m intervals along the backbone.
- Detachable streamers constructed from dual-strand pallet strapping in red and gold, fused at the top with heat shrink.
- A welded “eye” at the streamer top with a shark clip secured by cable ties for rapid deployment and removal.

The use of colour-coded matching between streamers and backbone markers provided guidance for correct streamer placement, reducing crew training requirements and deployment error.

Details for Tori line designs A, B and C can be found in **0.** AFMA issued scientific permits for a short-term evaluation of the *Tori Line C* design in November 2024 to the same five project vessels for qualitative assessment of handling, deployment, and crew feedback (AFMA Permit IDs 2024/R11–R15).

2.2.6 Manufacture and Deployment

Tori Lines A and *B* were manufactured by a commercial fishing chandlery in Mooloolaba, Queensland. Both were built to the above specifications and underwent full quality assurance checks prior to deployment.

Tori Line C was constructed directly by the Project Manager. The detachable design and colour-coded spacing system aimed to streamline deployment and ensure correct 7 m spacing across all vessels. Final products were hand-delivered to vessels, accompanied by in-person demonstrations and visual guides.

Table 2.1 Tori line configurations and materials used in the trial, including backbone, streamer and attachment characteristics.

	Tori line A	**Tori line B**	**Tori line C**
Backbone diameter (mm)	Fujiyama mainline 3.2mm	Sekiyama braid 2.5mm	Dyneema 2mm
Trailing line	Fujiyama mainline 3.2mm	Sekiyama braid 2.5mm	Fujiyama mainline 3.2mm
Connection to mainline	Permanent	Permanent	Crimped mainline loop with bimini knot, streamlined with heat shrink tubing
Streamer material	Paired light duty packing tape / heavy duty pallet strap	Beautori tubing	Paired heavy duty pallet strap, heat welded join
Streamer connection	Size LL Crimp	25mm Crane swivel	Shark clip
Streamer spacing (m)	3.5	5	7
Streamer connection method	Material ends folded and crimped directly to line	Beautori end folded through crane swivel and cable tied	“Eye” welded in pallet strap and shark clip attached via cable tie
Backbone connection type	Fixed	Fixed	Detachable
Distance to first streamer (m)	10	10	10
Number of streamers	25	14	8

Note - Values represent nominal design specifications for each tori line configuration as constructed and deployed during the trial.

2.3 Assessing tori line deployment and storage options

Following initial trials and results, capacity existed to improve tori line designs. Specifically, the proposed work aims to test the following:

- Two tori lines with 7m spacing and lightweight fixings that are “paired” and “offset” with each other and deployed port and starboard at the same time on adjustable arms
- Compare tested tori lines (AFMA regulated 3.5m spacing, 5m Sekiyama backbone) with new 7m 2mm Dyneema -version.
- Tori lines to be deployed simultaneously and observed under changing fishing conditions.

2.3.1 Developing tori line storage systems

The common method for storing tori lines in the longline fishing sector is using blue plastic 200l drums cut in half (**Figure 2.30**). These drums, typically used for transporting various materials, are recognised as food-grade or non-hazardous due to their colour coding. However, storing tori lines in drums can lead to tangles and WHS problems when being deployed. As a result, the use of a wheel or spool for the tori line was explored.

Storage wheels offer a potential solution for maintaining tori line condition and managing safe deployment and retrieval. For example, a mechanised system, such as an electrically driven storage wheel, could address storage challenges while automating line retrieval, reduce crew fatigue and repetitive strain.

This project assessed different deployment and storage options allowing lines and materials to be tailored to environmental conditions to optimise effectiveness and safety.

Figure 2.3 Common industry method for storing tori lines using modified 200l plastic drums, illustrating typical storage practices and associated handling considerations.

2.4 Investigating an adaptive optimised tori line design

This research project assessed existing tori line design (**0;Figure 2.4**) and storage, tested performance under varying environmental (sea state) conditions, and identified how key findings can be incorporated into an adaptive, optimised tori line system to significantly improve tori line coverage of the seabird interaction risk area.

The objectives for an adaptive tori line design are to ensure

- Deployment options for single or paired tori lines
- Ability to offset streamers when operating paired lines
- Quick-release capability if entanglement with longline gear occurs
- Flexible streamer configuration and material options
- Safe and efficient storage, deployment and retrieval
- Adjustable trimming of single or paired lines for maximum coverage of the seabird interaction risk area in all weather and sea states
- Increased protection of baited longlines from scavenging seabirds (**Figure 2.5**).

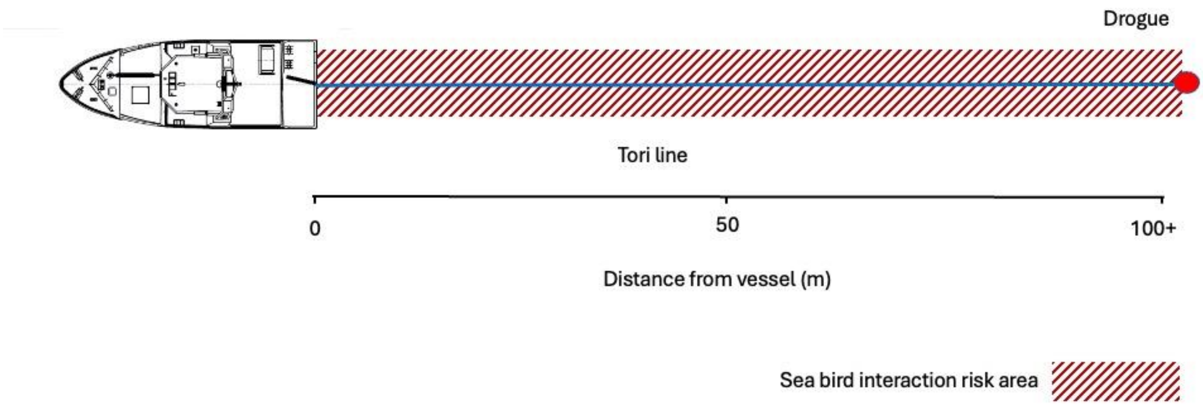


Figure 2.4 Schematic aerial view showing the area of reduced seabird access to baited hooks when a single tori line depicted in blue is deployed during line setting.

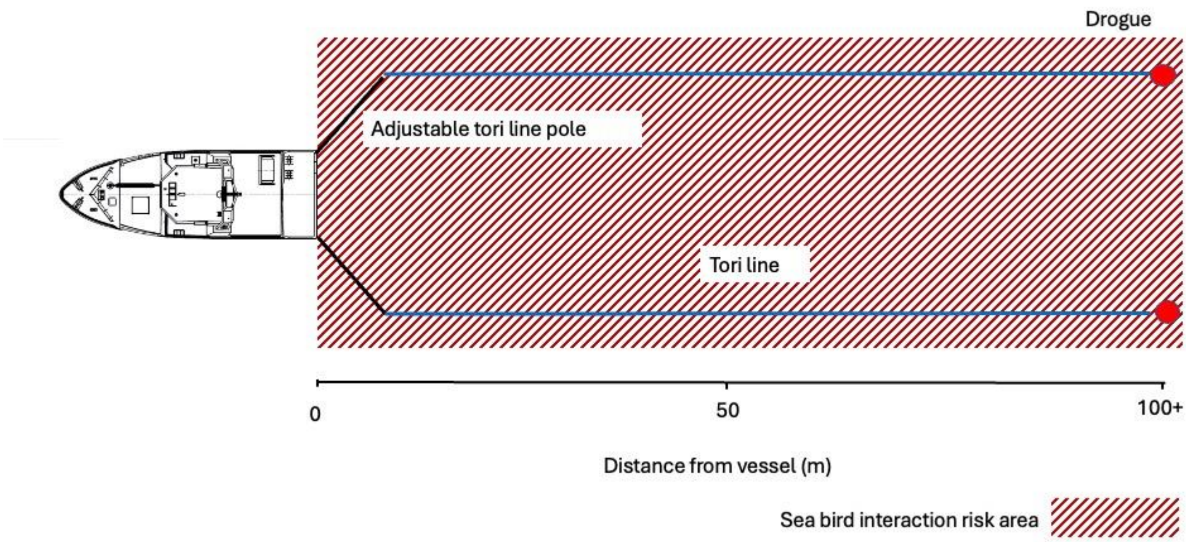


Figure 2.5 Schematic aerial view showing the expanded area of reduced seabird access when dual tori lines are deployed depicted in blue using adjustable poles to maintain coverage under varying environmental conditions.

2.5 Improving crew safety by revising the design and deployment of line weighting

Fishers in the ETBF operating below of 25°S must weight longlines to assist with accelerating the sink rate to place baited hooks out of the reach of scavenging seabirds with either a minimum of the following options (AFMA, 2025) (**Figure 2.6**)

- 60g weights at a distance of no more than 3.5m from each hook, or
- 98g weights at a distance of no more than 4m from each hook, or
- 40g weights immediately adjacent to the hook, or at no more than 0.5m from the hook, with dead, non-frozen baits attached to the hooks, or
- a hook-shielding device attached and deployed directly to each hook according to minimum branch line specifications.

Figure 2.6 Line-weighting configurations commonly used in the ETBF, including (1) 90 g Glo Lead, (2) 60 g lead swivel and (3) 45 g lead swivel, illustrating variation in weight and positioning relative to the hook.

Several line-weighting configurations are currently used within the fishery to achieve required sink rates while maintaining catch performance. The most common industry configuration consists of a 60 g weighted swivel positioned within 3.5 m of the hook, which has proven to provide a consistent balance between sink rate and catch rate of target species. In some cases, a 45 g weighted swivel is placed up to 1 m from the hook. While effective for improving sink rate, placing weighted swivels close to the hook can reduce the effectiveness of monofilament branchlines in mitigating shark interactions. This occurs because the shorter distance between the hook and weighted component reduces the length of monofilament available to part when bitten or abraded by sharks, increasing the likelihood that hooked sharks remain attached to the gear. Placement of weights close to the hook may also contribute to recoil events when hooks tear free during hauling operations. In addition, weighting positioned close to the hook can influence bait presentation and restrict the natural movement of live bait, and squid in ocean currents which fishers report impact swordfish catch.

An alternative approach to line weighting was explored through the development of the 90 g Glo Lead during a research project in 2012 (Abery et al., 2015). These luminescent weights are attached to the branchline using a crimped ferrule. When the line becomes taut and stretches, its diameter decreases, allowing the weight to slide along the line or come to rest at the hook if the hook is bitten off or the line parts. While this design was intended to reduce the severity of recoil events, partial flyback has still been observed, and in some cases the sliding weight has stripped the hook from the branchline. Fishers have also reported reluctance to adopt this system due to increased hook-bin tangles, line stiffening and perceived decrease in bait attractiveness.

Against this background, the research aimed to improve the safety and operational performance of line-weighting systems while maintaining effective sink rates and protected species mitigation and catch outcomes. This was addressed through a combination of field trials and simulation-based assessment of alternative weighting approaches.

2.5.1 Redesigning the 90g Glo Lead

A modified version of the Glo Lead was developed, incorporating a 50% reduction in length to improve flexibility and bait presentation, and a 33% reduction in weight to 60 g. The ferrule attachment method was retained to enable direct comparison with the original design (**Figure 2.7**).

The research aimed to improve the safety of line weighting by testing several approaches both in the field and through simulation.

Figure 2.7 Modified 90 g Glo Lead design, demonstrating reduced length and weight and the ferrule attachment mechanism allowing the line to pass through the weight and clamp in place.

2.5.2 Procella Mk I and II

The *Procella* hook configuration, designed by Mr Nigel Brothers (Humane Society International), incorporates a 45 g weight integrated directly into the hook. Two prototype variants were developed. Procella Mk I was manufactured by weld-fixing the weight to the hook shaft, while Procella Mk II was manufactured by forging a lead sinker around the hook shaft (**Figure 2.8**). These configurations were included to assess whether integrating weight at the hook could achieve sink rates consistent with ACAP best-practice guidance, while maintaining shark bycatch mitigation performance and reducing the potential for recoil events associated with separate weighted swivels.

Figure 2.8 Procella hook-integrated weighting systems, including Mk I (left) and Mk II (right) designs, illustrating integration of weight directly onto the hook to influence sink rate and recoil behaviour..

2.5.3 Yamazaki Double-Weighted Branchline

A double-weighted branchline (DBL) configuration developed by Kazuhiro Yamazaki, Fishing Master of the F/V *Fukuseki Maru No. 5*, (**Figure 2.9**) integrates weighting in a manner intended to achieve effective sink rates while reducing the severity of recoil when a hook comes free under tension during hauling. The DBL configuration has been recognised internationally for its innovative approach to balancing seabird mitigation and crew safety and was awarded the Smart Gear Award in 2011(Kazuhiro, 2025).

Building on this concept, the present study included simulation-based assessment of flyback behaviour across a range of standard and modified branchline configurations.

Flyback simulations were conducted to evaluate recoil trajectories, impact behaviour and interaction with protective equipment using the following gear configurations:

- Standard and novel gear using a ID62 flyback bar replication.
- Yamizaki double-weighted branchline (DBL)
- Modified DBL variant
- Standard, novel and double leaded gear into flyback screens.

Figure 2.9 Yamazaki double-weighted branchline configuration tested under controlled conditions, designed to achieve effective sink rates while reducing recoil severity.

2.6 Assessing hook shield devices to improve seabird mitigation

Hook-shielding devices were considered during project development as part of the broader assessment of available seabird mitigation technologies. These devices are designed to physically shield baited hooks during line setting and thereby reduce seabird access to hooks prior to reaching target sink depths and are one of two stand-alone ACAP-endorsed “best practice” seabird mitigation device designed to prevent seabirds from accessing baited hooks during line setting.

2.6.1 Smart Tuna Hook

The Smart Tuna Hook (STH), developed by Hans Jusseit in 2008. The system encloses the hook point and curvature within a cap-like steel dome that is secured to a specialised hook using a biodegradable magnesium pin (**Figure 2.10**). The pin corrodes in seawater, releasing the dome once the hook has sunk beyond the diving range of scavenging seabirds.

The STH was previously evaluated under FRDC Project 2008/078 and subsequently trialled in international longline fisheries, including the South African pelagic longline fishery (Baker et al., 2016). These trials demonstrated up to 91% reductions in seabird and turtle interactions without measurable impacts on target catch rates. The device also received public recognition, winning the ABC *Inventors* People’s Choice Award.

Despite demonstrated technical feasibility, the STH employs a single-use shielding dome.

At an estimated unit cost of approximately AUD $0.32 per dome (2016 pricing), widespread deployment was considered likely to be uneconomical for the ETBF, except potentially in areas of consistently high seabird abundance.

A related concept involving hook banding, based on attaching the hook directly to a weighted component was considered during the project design phase but did not proceed to field or simulation testing.

2.6.2 Hookpods

Hookpods are commercially developed hook shielding devices originating from work commenced in 2005 by Ben and Pete Kibel, in collaboration with bycatch specialist Dr Ben Sullivan. The device is designed to encapsulate the hook during deployment and release it automatically once a predetermined depth is reached, thereby reducing seabird access during the most vulnerable phase of line setting (Sullivan, 2017; 2025). Two principal Hookpod configurations were identified during the review process:

- the Hookpod Mini, which mechanically shields the hook during setting operations; and
- the Hookpod LED, which incorporates an integrated light-emitting diode (LED) intended to replace the use of disposable chemical light sticks commonly used in some pelagic longline fisheries.

Published studies have demonstrated that hook-shielding devices can be effective in reducing seabird interactions under certain operational conditions (Silva-Costa et al., 2017; Goad et al., 2019). Hookpod systems have been reported to achieve substantial reductions in seabird bycatch while maintaining target catch rates in some pelagic longline fisheries.

Notwithstanding these findings, the present project prioritised mitigation systems considered most operationally applicable to the ETBF fleet within the available project resources and research approvals. Practical considerations identified through industry consultation included integration with existing vessel infrastructure, operational handling characteristics, deployment complexity, cost and potential implications for work health and safety during commercial fishing operations.

As part of this study, the Hookpod Mini (**Figure 2.10**) was tested under controlled conditions to assess its operational performance within the context of the broader mitigation configurations examined.

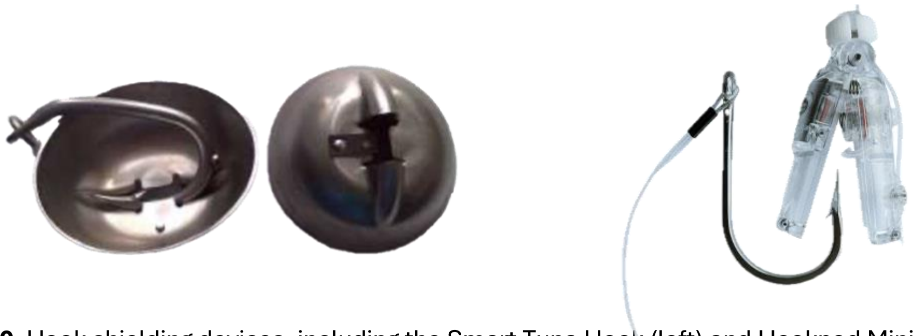


Figure 2.10 Hook shielding devices, including the Smart Tuna Hook (left) and Hookpod Mini (right), showing mechanisms for enclosing the hook during deployment and releasing it at depth to reduce seabird access. Photo: Barry Baker.

2.6.3 Underwater Bait Setter

The Underwater Bait Setter (UBS) is the other stand-alone ACAP-recognised "best practice" seabird mitigation device designed to reduce seabird interactions by deploying baited hooks below the waterline (**Figure 2.11**) beyond the known diving depth of most vulnerable seabird species. The UBS is a stern-mounted, hydraulically operated system that delivers baited hooks within a steel capsule to depth prior to release.

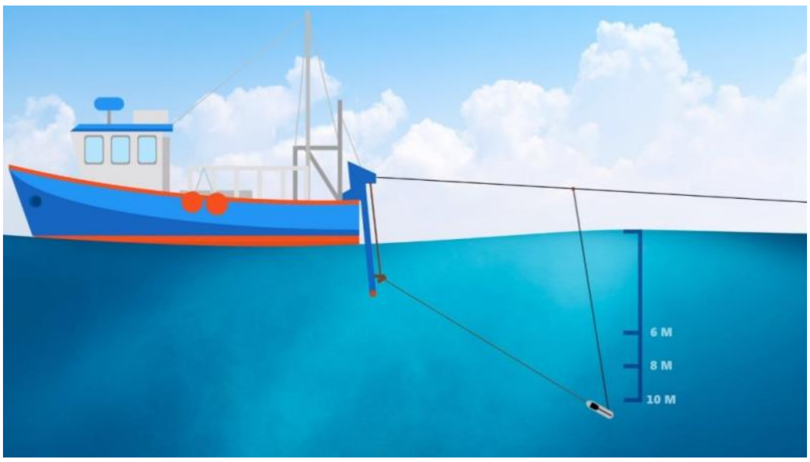


Figure 2.11 Conceptual design of an underwater bait setter (UBS), illustrating the deployment of baited hooks below the water surface to reduce seabird interactions. Source: Skadia.

Conceptually, the UBS has potential to further reduce seabird interactions in pelagic longline fisheries. However, the UBS design is vessel specific, safety considerations are unknown, and its efficacy when used with live bait, particularly in tuna longline fisheries, remains uncertain. Approximately 50% of annual fishing effort in the ETBF involves the use of live bait, making the performance of the UBS under live-bait conditions a critical consideration for industry uptake.

Early in the project, proponents of the UBS were engaged with the intention of conducting a live-bait trial on an ETBF vessel.

The proposed trial involved installation of a UBS unit on a commercial tuna longline vessel and collection of operational and biological data to assess impacts on WHS, bait viability, fishing efficiency and seabird interactions. Funding for the device installation was committed by the UBS proponents.

To support rigorous evaluation, Tuna Australia coordinated the sourcing of a PhD candidate from the University of the Sunshine Coast (UniSC) to lead analysis of trial data and worked with industry to identify a suitable project vessel and schedule slipping for device installation.

Further information on the UBS can be found at the following website viewed on 1 February 2026 - https://www.bmis-bycatch.org/mitigation-techniques/underwater-setting-techniques

2.7 Investigating physical protection systems to safeguard crew against flybacks

Fishing crews may use personal protective equipment (PPE), including helmets, safety glasses or visors, and reinforced vests, to reduce the risk of injury from flyback events. While PPE can provide individual protection, continuous use during all fishing operations is not always practical and may introduce additional operational constraints, particularly under variable sea-state conditions.

As part of this project, consultation with tuna fishing crews was undertaken to identify alternative engineering controls that could be evaluated to reduce flyback risk at the vessel level.

Based on this consultation, two concepts were prioritised for further development: a flyback safety screen and a flyback bar. Both devices were selected for proof-of-concept design and evaluation within the broader suite of flyback mitigation approaches assessed in this study.

2.7.1 Flyback safety screen

The flyback safety screen was developed as a proof-of-concept system to assess the feasibility of a physical barrier for mitigating flyback hazards on longline fishing vessels. An additional objective was to examine the potential for dual-purpose functionality, including the provision of ultraviolet protection for crew during hauling operations.

The screen concept comprises a strengthened gauze-type barrier positioned to hang over the winching block and hauling stations. The system is designed to be retractable, either by rolling or lifting the screen clear of the working area when not required, or by mounting the screen on a rod that allows lateral retraction in a curtain-like configuration. The lower edge of the screen is intended to be secured using fixed or elasticised stays, or alternative hardware, to maintain separation from the gunwale line and ensure the barrier remains deployed under variable wind and vessel movement conditions.

Key design and material selection criteria included:

- adequate perforation to maintain line-of-sight and operational visibility
- demonstrated ultraviolet protection factor (UPF) suitable for marine environments
- commercial availability to enable ease of procurement and replacement
- compatibility with marine-grade attachment hardware without compromising material integrity
- resistance to degradation from prolonged exposure to ultraviolet radiation and saltwater

A desktop review of commercially available materials identified two candidate products for prototype fabrication and field trials:

- **Hortshade**, a Ultra Violet-stabilised LDPE woven monofilament mesh (200 Grams per Square Metre, reported tensile strength 1,485 Nm), typically used for shade structures, barrier mesh and tension netting.
- **Spidermesh**, a UltraViolet-stabilised PVC woven mesh (350 Grams per Square Metre, reported tensile strength 1,650 Nm), commonly utilised for cargo containment (e.g. tonneau covers) and industrial safety barriers, and widely available in various dimensions through automotive and hardware suppliers.

Prototype screens were fabricated in collaboration with a local shade sail manufacturer using both Hortshade and Spidermesh materials. A conceptual installation layout (**Figure 2.12**) was developed for a “Westcoaster”-style commercial fishing vessel, including proposed attachment points, tensioning systems and stowage arrangements (**Figure 2.13**). Options for maintaining appropriate screen tension were identified for evaluation, including elasticised stays and fixed-frame assemblies.

Flyback simulation testing was used to assess the screen’s capacity to arrest or deflect projectiles under controlled conditions, with emphasis on validating material performance and identifying suitable tensioning configurations. Performance under simulated operational loads, environmental exposure and repeated deployment cycles was recorded to inform recommendations for design refinement and potential future vessel integration.

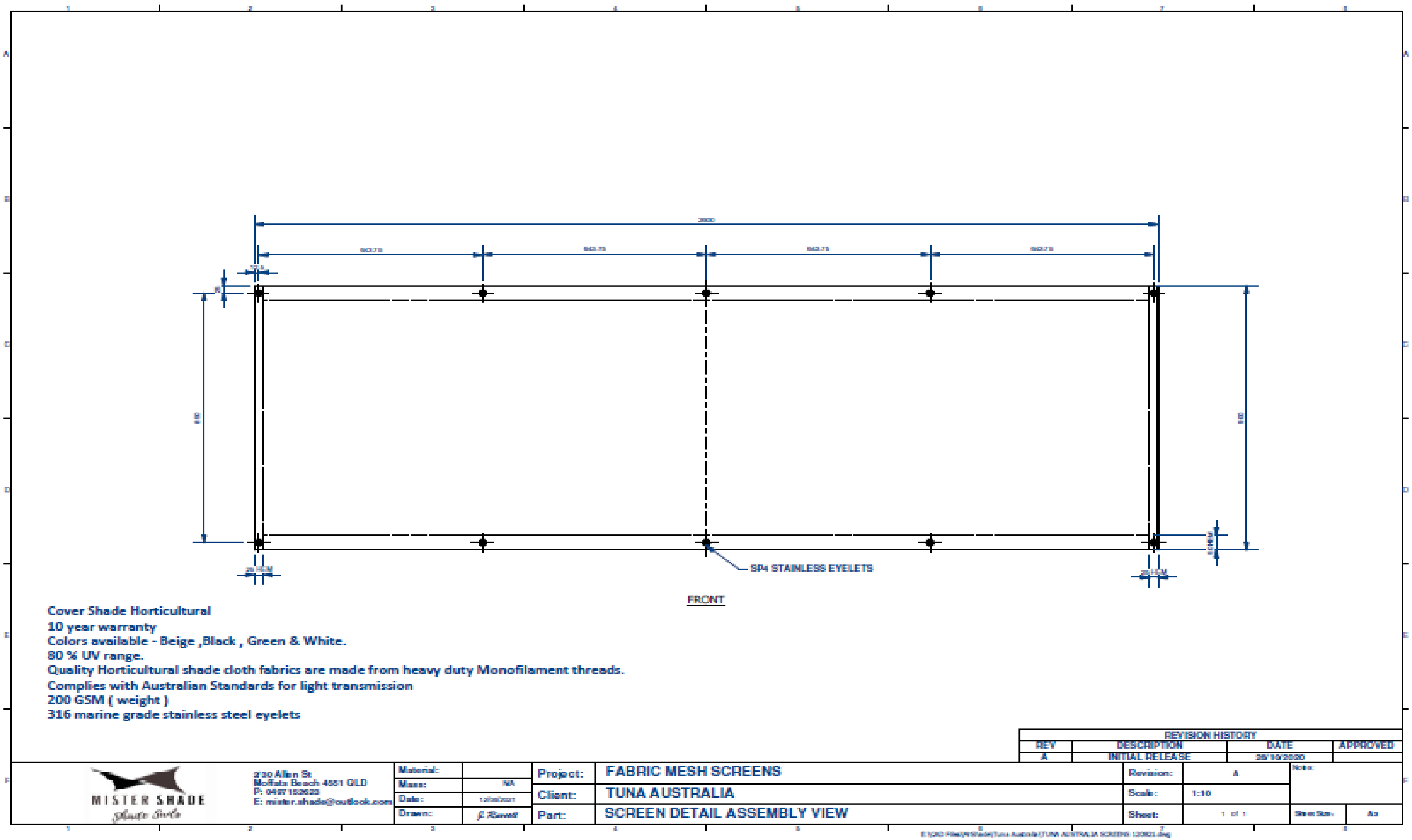


Figure 2.12 Conceptual design and specification of flyback safety screen systems for trialling, illustrating proposed configuration and material application..

Figure 2.13 Installed flyback safety screens on commercial fishing vessels, demonstrating visibility, coverage of working areas and retractable design for operational use.

2.7.2 Flyback safety bar

The flyback safety bar was developed as a proof-of-concept engineering control to assess the feasibility of a fixed physical barrier for reducing the risk of flyback injuries during longline hauling operations. The concept focuses on intercepting or deflecting recoiling terminal gear before it can reach crew working positions, while maintaining clear access to hauling equipment and preserving normal deck workflows.

Two flyback safety bar configurations were developed to suit the operating arrangements, deck layouts and hauling systems of two large steel longline vessels within the Tuna Australia fleet. Design considerations included compatibility with existing vessel structures, minimising interference with fishing operations, and the ability to integrate the bar into routine deck activities without increasing operational complexity.

Design A

Consists of a steel tubular frame mounted on folding stanchions, positioned to deploy over the hauling block and adjacent bin stations (**Figure 2.14**). A secondary, smaller-diameter tubular element is incorporated on the aft side of the frame and can be extended to increase the protected area when required (**Figure 2.15**).

The configuration is intended to modify the geometry of branchline retrieval during landing by guiding the branchline between the gunwale and the safety bar. In the event of a hook tearing free or being bitten off under tension, recoiling terminal gear is directed toward the safety bar or vessel structure rather than the crew working area. Horizontal support members are included to provide coverage above the gunwale height, addressing potential recoil trajectories that extend beyond the gunwale line.

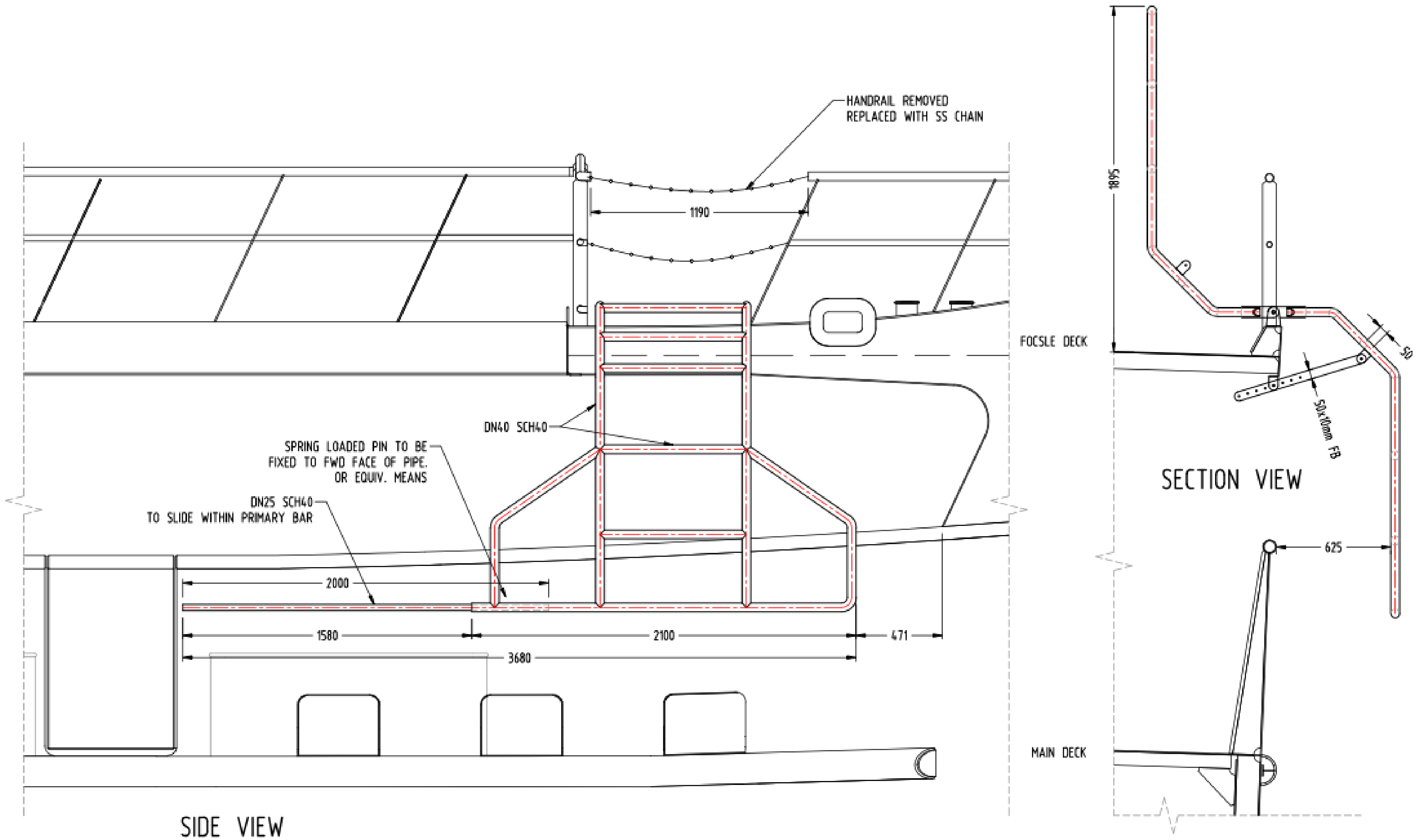


Figure 2.14 Flyback safety bar design showing side and section views, illustrating configuration for intercepting recoiling gear during hauling operations.

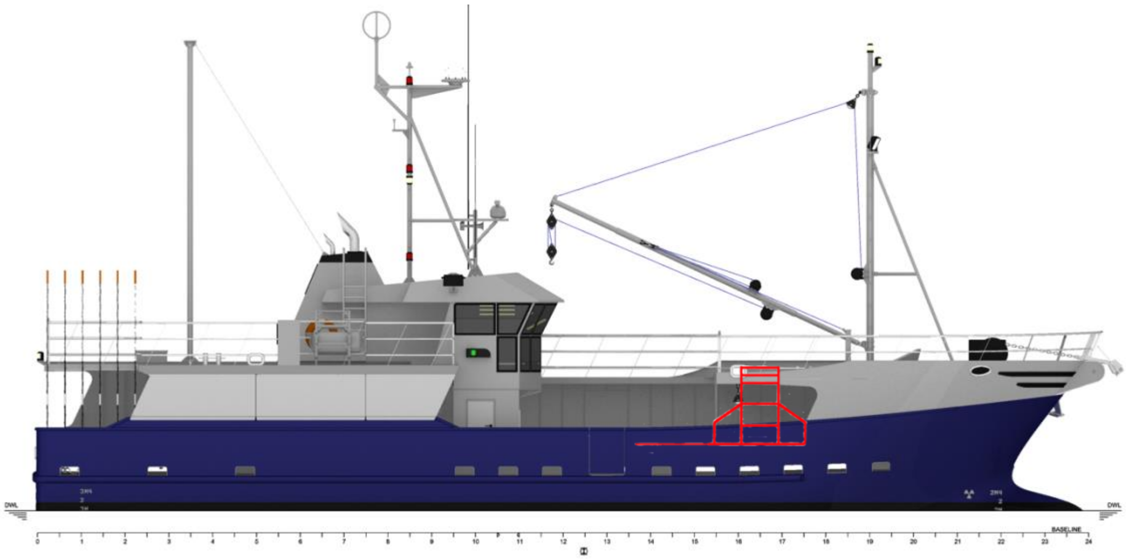


Figure 2.15 Flyback safety bar installation on an aft wheelhouse tuna longline vessel, showing extension of the bar to deflect recoiling gear toward the vessel hull and away from crew working areas.

Design B

Design B consists of oversized 62 mm steel tubing mounted on stanchions and configured to extend outward and below the gunwale line, consistent in principle with Design A. This configuration adopts a modular, multi-component construction. Primary support elements slide outward from above the shelter deck, with horizontal flyback bar sections locked into position during deployment.

A curved section is incorporated forward of the hauling block to facilitate smooth passage of branchlines from the block to the next crew member handling the line. At the request of the vessel owner and Fishing Master, a larger-diameter tube was selected to minimise branchline wear and improve durability under rough sea conditions.

The flyback bar system is designed to allow complete disassembly when not in use. This requirement reflects operational constraints of the project vessel, which is based in Mooloolaba, Queensland, where tidal conditions necessitate unobstructed starboard access for mooring. In addition, the vessel's port-side shelter deck limits servicing and resupply operations to the starboard side only. Images can be found in Appendix 13.

Placement of the flyback bar relative to typical crew hauling positions, and the range of potential recoil trajectories, was informed through in-port scenario testing and consultation with vessel operators. Consideration was also given to the work health and safety (WHS) implications of deploying and stowing the system under varying sea and operating conditions.

The flyback bar systems were designed by OceanTech and manufactured in Mooloolaba, Queensland, before installation on two Tuna Australia member vessels. Vessel operators were consulted following installation to document operational feedback relevant to system integration and handling.

2.8 Operational feasibility and cost-effectiveness of mitigation tools

2.8.1 Industry surveys

Industry surveys were undertaken to establish a baseline understanding of ETBF practices and to inform the selection and evaluation of mitigation tools with respect to operational practicality, usability and cost-effectiveness. The survey process comprised a combination of in-person vessel visits, structured interviews and follow-up questionnaires, as documented in Appendix 1.

An industry consultation road trip was conducted between 12 and 28 March 2021, covering the ports of Coffs Harbour, Nelson Bay and Ulladulla. The purpose of the consultation was to document fishing gear configurations, crew practices, bycatch mitigation measures and vessel layouts, and to capture operator experience and attitudes relating to WHS and seabird mitigation. This information was used to establish a baseline against which new or modified mitigation tools could be assessed.

The consultation period coincided with significant rainfall and flooding along the New South Wales north and south coasts, which constrained access to some ports and vessels. Despite these conditions, 11 vessels were surveyed through wharf-based interviews during the road trip, with an additional phone interview conducted with the former owner of a side-setting vessel. When combined with 11 vessels surveyed previously in Mooloolaba, the consultation captured information from 23 vessels, representing a substantial proportion of the active ETBF fleet of 32 vessels with results interpreted as indicative rather than statistically complete fleet-wide estimates.

Survey outputs, summarised in Appendix 1, provided detailed information on existing mitigation practices, gear configurations, operational constraints and perceived WHS risks. These data were used to guide project priorities, identify mitigation concepts suitable for further development, and inform decisions regarding which tools warranted field testing, simulation or proof-of-concept evaluation.

In addition, participating Tuna Australia members completed a targeted follow-up survey during the project to support assessment of new and modified mitigation tools and processes. This survey specifically sought feedback on ease of use, compatibility with existing operations, perceived safety benefits and cost considerations, providing qualitative input to the evaluation of cost-effective and operationally practical mitigation options (Appendix 1).

Survey participation was voluntary and relied primarily on existing industry communication pathways available through Tuna Australia and participating operators.

While the survey captured a substantial proportion of active ETBF vessels, responses may not fully represent the views or practices of all operators within the fishery.

2.9 Evaluate mitigation and personal protection technology in controlled flyback simulations (CFS) at the Australian Maritime College (AMC) Underwater Collision Research Facility

Controlled flyback simulations were conducted at the Australian Maritime College (AMC) Newnham Campus in August 2023 and August 2024. The Underwater Collision Research Facility (UCRF) was engaged to provide the controlled testing environment and to undertake data capture and analysis (AMC, 2025). The simulation program was led by Dr Roberto Ojeda, supported by science technicians and data analysts.

Previous flyback simulation studies at AMC (McCormack and Rawlinson 2016) utilised a flume tank to test recoil events originating both below and above the waterline. For the present study, testing focused on worst-case scenarios, consistent with earlier findings that flybacks originating above the waterline can generate higher recoil velocities and impact forces (McCormack and Rawlinson, 2016). This approach aligns with the project's emphasis on evaluating mitigation performance under the highest-risk operational conditions described in 2.7).

Detailed simulation methodologies are provided in the two flyback simulation reports. In brief, all branchline configurations were initially tested without the use of flyback protection devices to establish baseline flyback velocities and trajectories. These baseline results provided a reference against which the performance of engineered mitigation devices could be assessed. Subsequent testing incorporated standard industry branchlines in combination with protective devices, including a flyback bar jig designed to replicate the flyback bar configurations installed on project vessels. Flyback bar sections were fabricated from 48 mm and 62 mm outside-diameter stainless steel tubing to match prototype dimensions described in 2.7

In addition, simulations assessed the performance of the flyback safety screen in intercepting or deflecting projectiles, consistent with the proof-of-concept design outlined in Section 2.7. Screen testing focused on whether projectiles were arrested or deflected away from the target crew area under controlled conditions.

Branchlines used in the simulations were constructed with precisely measured upper and lower sections, with minimal waste at crimped joins, to ensure consistency across treatments. A total branchline length of 14 m was used for all configurations. While this length is shorter than the typical industry branchline length of approximately 10 fathoms (~18 m), it was selected to replicate realistic flyback scenarios at distance while remaining compatible with the constraints of the testing environment.

Industry consultation (Section 2.7; Appendix 1) indicates that flyback events most commonly occur under three operational scenarios:

1. When the branchline is unclipped from the mainline, causing a sudden change in fish direction and increasing the likelihood of a tear-out or bite-off;
2. Shortly after manual fighting begins, particularly with billfish which often jump or run once tension is applied following retrieval of several wraps of leader; and
3. Immediately prior to landing, when hooks may pull free as fish are brought to the sea door for gaffing.

The 14 m branchline length was considered appropriate for replicating the first two scenarios, which are associated with higher recoil velocities and greater impact risk. The third scenario was not prioritised for testing, as at this stage of retrieval the line-weighting device is often already in hand, substantially reducing the likelihood and severity of flyback events, as discussed in Section 2.5.

Previous flyback studies conducted at AMC used 12 m branchlines, reflecting earlier industry advice and constraints of the flume tank testing environment at the time (McCormack & Rawlinson, 2016).

Branchline diameter and hook specifications were selected based on industry consultation and sales data for commonly used consumables (Appendix 1). A 1.8 mm monofilament branchline was used, consistent with standard ETBF practice, together with size 13/0 ringed live-bait hooks. The ring component of the hook was identified as a potential structural weak point and was therefore considered suitable for assessing hook behaviour under simulated flyback conditions.

The branchline configurations tested across the two simulation events are summarised in **Table 2.2**.

Table 2.2 Branchline configurations tested under controlled flyback simulation conditions at the Australian Maritime College Underwater Collision Research Facility.

Configuration Type	Total length (m)	Branchline diameter / Breaking Strain	Top section (length of branchline (m)	Bottom section (m)	Mitigation Weight (g)	Hook type	Notes
Industry Standard	14m	1.8mm (400lb)	10.5m	3.5m	60g swivel	13/0 live bait	Industry standard
Modified safety lead	14m	1.8mm (400lb)	14m	n/a	60g sliding lead (modified)	13/0 live bait	Shortened lead
Hookpod (mini)	14m	1.8mm (400lb)	14m	n/a	Hookpod hook shield	13/0 live bait	HP mini locked in open (fishing) position at 1m from hook
Procella (version 1)	14m	1.8mm (400lb)	14m	n/a	34g weight welded to hook	16g sz 16/0)	Cetacean friendly hook – 4.5mm diameter hook gauge
Yamazaki double weighted leader	14m	1.8mm (400lb)	10.5m	2.3m	65g sleeved wire with 2 x sinkers	13/0 live bait	Middle section of 1.2m sleeved wire with fixed 30g sinker and sliding 20g sinker
US / NZ standard	14m	2.1mm (450lb)	13m	1m	45g	13/0 live bait	Note larger diameter branchline on advice from US / NZ
Procella (version 2)	14m	1.8mm (400lb)	14m	n/a	40g on hook	22g sz 16/0)	Safe coating on lead
98g Sliding lead	14m	1.8mm (400lb)	14m	n/a	100g sliding lead (97g-101g)	13/0 live bait	Lead locked steadfast at 4m to mimic regulated line weighting

Note - Configurations represent standard and modified gear setups used to assess recoil behaviour under controlled conditions.

Some of these mitigation devices have also been evaluated for sink rate performance or incorporated into related work under companion project 2021–078.

2.10 Develop a suite of extension products to maximise communications with fishers

One of the key challenges in applied research projects is the development of extension materials that effectively communicate project outcomes to diverse audiences within an increasingly complex communications landscape.

The extension component of this project was designed to ensure that research findings were accessible, relevant and actionable for intended users, while also meeting broader stakeholder expectations for transparency and accountability. Extension objectives included supporting informed decision-making by fishing operators, improving awareness of practical mitigation options, and facilitating uptake of cost-effective and operationally feasible tools across the fleet.

To achieve these objectives, a suite of extension materials was tailored to multiple target audiences, including commercial fishing operators and crew, fisheries managers and regulators, researchers, and other industry stakeholders. The development, coordination and management of all extension materials for this project were led by Ms Kate Bevitt, working in partnership with Tuna Australia and Cultivate Communications Australia Pty Ltd, with content and formats selected to align with contemporary communication standards and stakeholder needs (Holmes, 2025).

2.11 Development of a protected species toolkit to support data collection, analysis and information sharing in the Eastern Tuna and Billfish Fishery

This component of the project was dependent on securing co-funding from other government agencies and was disappointingly not implemented. The intended outcomes of this component are being progressed through FRDC Project 2021-078.

3. Results

To trial several new and/or modified protected species mitigation tools and processes in the Eastern Tuna and Billfish Fishery to further reduce the rate of protected species interactions

Figures and tables are presented with clearly defined axes, units and self-contained captions to ensure interpretation without reference to the main text. Behavioural and performance categories are defined in the Methods section and applied consistently throughout.

3.1 3.5m versus 5m streamer spacing trial

3.1.1 Trial effort

Sea trials were conducted between 1 November 2021 and April 2022 to compare tori lines with 3.5m and 5m streamer spacing. Scientific permits were issued by AFMA to five project vessels. Trial activity was substantially affected by COVID-19 disruptions, including inconsistent fishing effort due to crew availability, market access constraints, and freight and logistics issues. In addition, the initial permit period overlapped with vessel maintenance and seasonal shutdowns for several operators, resulting in lower-than-anticipated data returns.

An initial sampling target was developed to support comparison between tori line configurations. However, the original power analysis was not available for independent review during preparation of this report. In principle, a fully powered design would require balanced replication across vessels, tori line configurations, bait types, lunar phases and environmental conditions. This would require substantially greater sampling effort than was achievable within the available budget, research approvals and operational constraints of the project.

The final dataset reflects the realities of conducting applied research in a commercial fishery, including COVID-related disruptions, vessel availability, weather, gear damage and skipper decision-making during normal fishing operations. As a result, replication across sampling strata was unbalanced.

Results from the tori line trials are therefore interpreted as descriptive and comparative evidence of operational performance under real fishing conditions, rather than as outputs from a fully powered experimental design.

Figure 3.1 Distribution of tori line configurations (A and B) deployed across participating vessels during the trial period.shows the distribution of tori line types deployed by each participating vessel during the trial period.

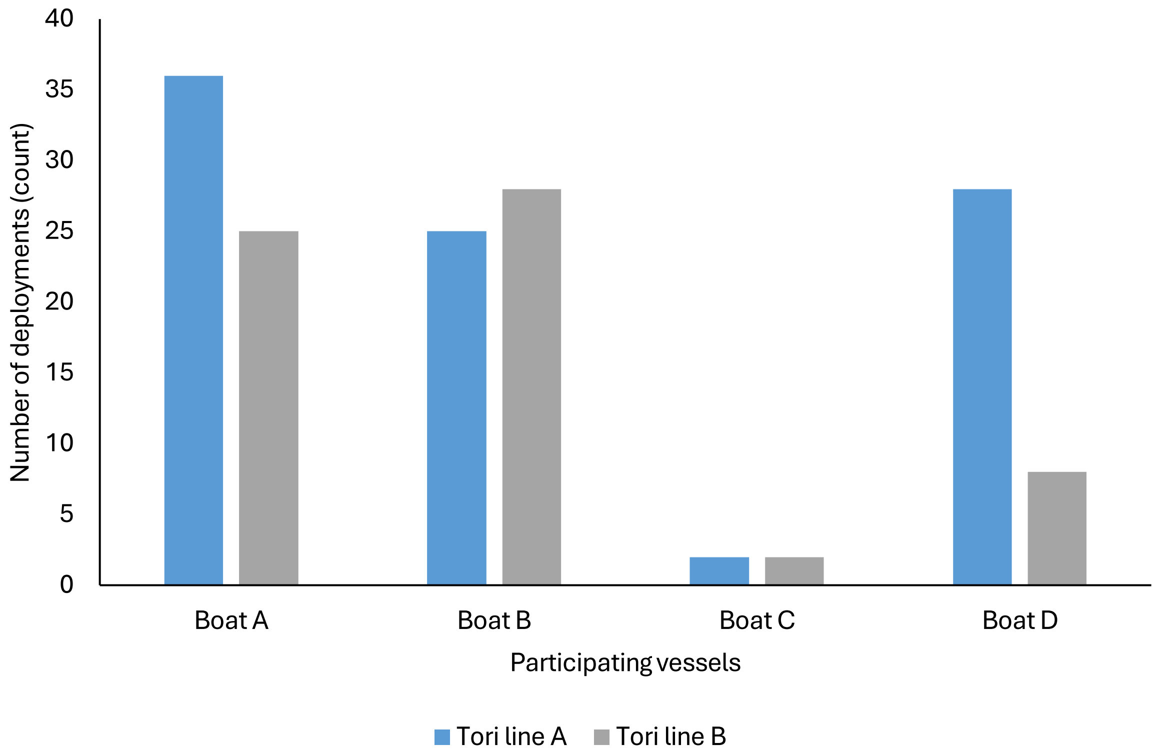


Figure 3.1 Distribution of tori line configurations (A and B) deployed across participating vessels during the trial period.

3.1.2 Data collected

To support comparison between tori line configurations, an initial target number of sets was developed to guide data collection. However, the final dataset reflects the realities of conducting research under commercial fishing conditions, including COVID-19 related disruptions, vessel availability and operational variability. A total of 154 sets were recorded across participating vessels, providing a substantial dataset for comparative assessment under a range of environmental and operational conditions.

Given the applied nature of the study, data were collected at the level of individual sets, with variables such as tori line configuration, seabird presence and behaviour, bait type and environmental conditions recorded where possible. These variables co-vary within commercial fishing operations and were not controlled as independent experimental strata. As a result, the dataset represents an unbalanced observational design rather than a fully replicated experimental framework and a formal statistical inference was not attempted.

Data analysis was therefore undertaken using a descriptive and comparative approach. Results are presented as counts, proportions and relative differences between tori line configurations and operational conditions. This approach enables identification of patterns in mitigation performance and seabird interactions under real fishing conditions.

Exploratory statistical analyses were undertaken to examine relationships within the dataset. However, given the unbalanced structure and lack of independent replication across all variables, results are interpreted as indicative of operational performance rather than as outputs from a fully powered statistical design. Accordingly, findings are therefore interpreted as indicative of mitigation performance under operational conditions and are not intended to provide statistically definitive comparisons across all variables.

3.1.3 Bait types used during the trial

Bait types varied among vessels and sets. As vessels operated predominantly in southern areas of the fishery, the use of a range of bait types, including live bait, was anticipated. Yellowtail was the most reported bait, followed by mixed bait types incorporating yellowtail and squid, and combinations of squid and pilchard. No vessels reported exclusive use of squid-only bait during the trial period. Some surveys reported the use of “all” bait types. However, it was unclear whether this referred to all three bait types or a subset thereof (**Figure 3.2**).

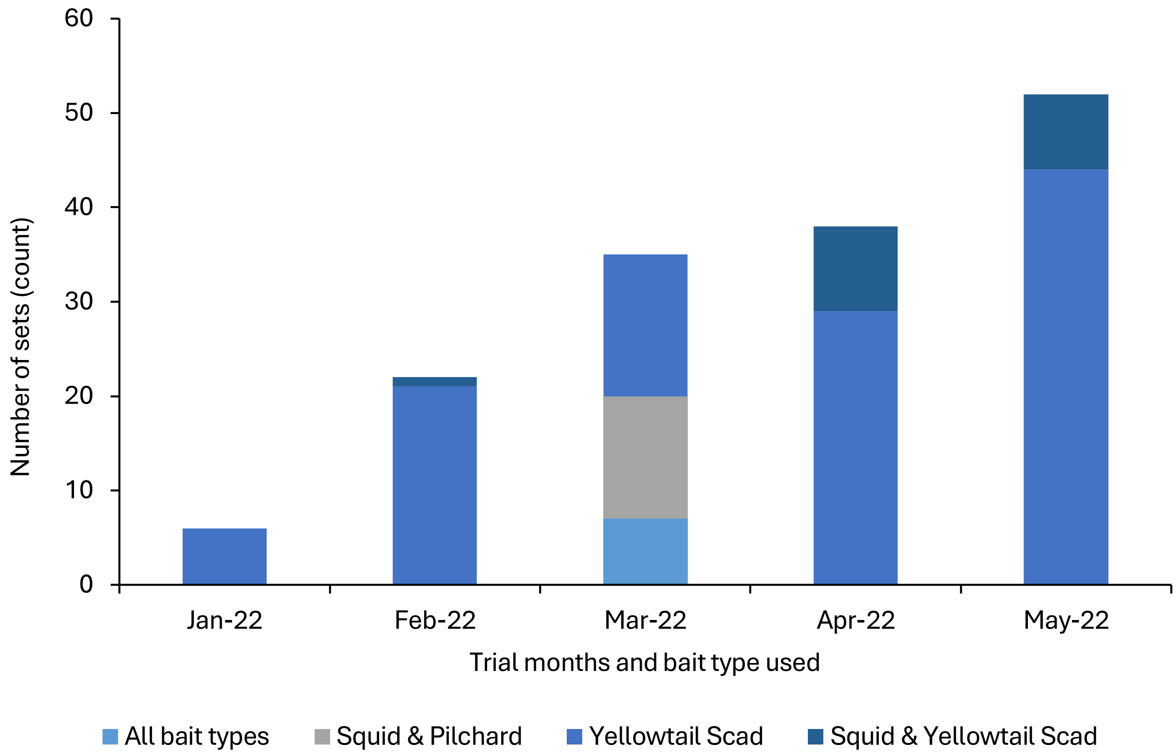


Figure 3.2 Bait types used during the sea trials and their relative frequency across all recorded sets.

3.1.4 Tori line hook-ups

A total of 31 tori line hook-ups were reported (**Figure 3.3**), representing approximately 20% of deployments. Notably, 11 hook-ups occurred during a single 10-day period characterised by wind strengths of 10–20 kts and operationally challenging deployment conditions. These events were associated with seabird mortalities reported by a single participating vessel.

Reported causes of hook-ups included poor aerial performance resulting in streamers dragging in the water, rough sea states, and interactions between tori lines and floats or beacons attached to the mainline.

Hook-ups were most frequently reported during deployments where tori line aerial performance was classified as poor or medium, indicating a relationship between reduced aerial extent and increased hook-up risk. Crew-reported causes of hook-ups consistently related to inadequate aerial coverage, including streamers dragging in the water, instability under rough sea conditions, and fouling interactions with the tori line.

Although Figure 3.3 shows differences in the total number of hook-ups recorded between tori line configurations, the operational variability within the dataset limited confidence in attributing these differences solely to tori line design. Hook-up occurrence was likely influenced by multiple interacting factors including vessel configuration, environmental conditions, deployment stability, operator experience and fishing practices during individual setting events.

The results suggest that hook-up risk was more strongly associated with overall aerial performance and deployment behaviour than with tori line configuration alone. In particular, instability or reduced aerial coverage under varying operational conditions appeared to increase the likelihood of hook-up events irrespective of the specific tori line design deployed.

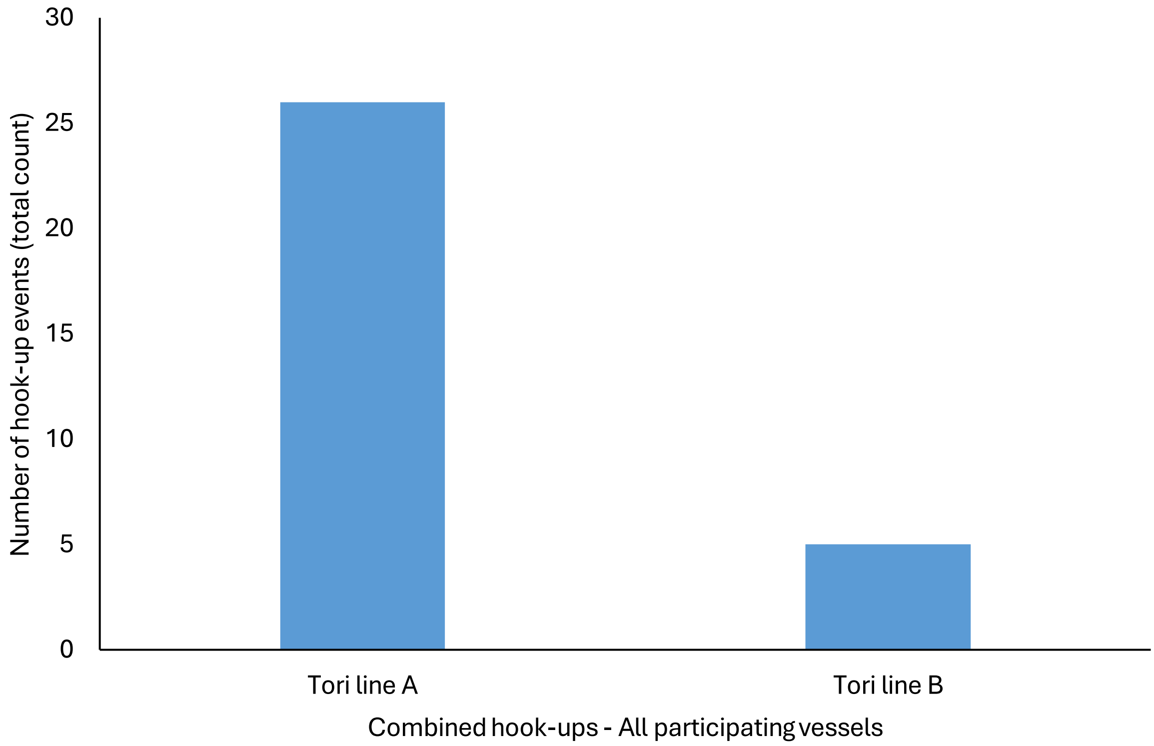


Figure 3.3 Number of tori line hook-up events recorded during the trial period across participating vessels. Hook-ups refer to interactions between tori lines and longline gear during deployment.

3.1.5 Seabird presence and behaviour

Three seabird groups were identified during the trial: Albatross, Shearwaters and Petrels. Shearwaters were the most frequently reported group (32.7%), followed by mixed assemblages of Shearwaters and Albatrosses (21.2%). Albatrosses alone were reported in 13.5% of observations, while Petrels accounted for 1.9%. In 30.8% of surveys, seabird species were not identified.

Seabird observations varied substantially across the trial period, ranging from zero to more than 1,000 birds observed during individual sets. Figure 3.4 presents seabird observations recorded across all sets undertaken during the trial period in relation to lunar phase.

While elevated seabird observations were recorded during some full moon and waxing gibbous periods, the distribution of observations likely also reflects the timing and concentration of fishing effort across the lunar cycle. Commercial longline operations commonly target periods surrounding the new and full moon phases to optimise fishing activity prior to vessels returning to port for unloading and reprovisioning. Consequently, increased seabird observations during some lunar phases may reflect increased fishing effort and vessel activity during those periods rather than a direct ecological response to lunar phase alone.

Considerable variability was present throughout the dataset, including several extreme observations, and the figure should therefore be interpreted as a descriptive representation of seabird observations during the trial period rather than evidence of a statistically significant lunar-phase effect.

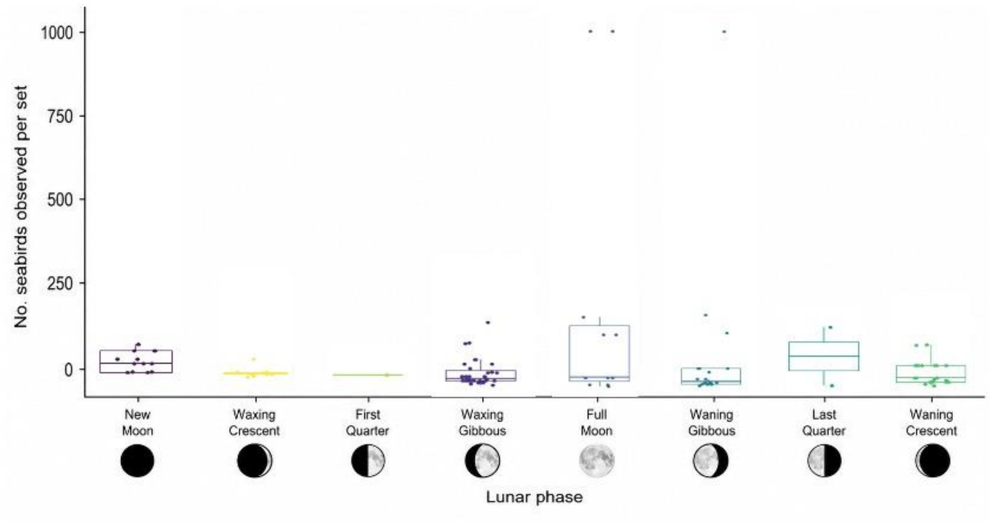


Figure 3.4 Box plot showing numbers of seabirds observed across lunar phases during the trial period, expressed as the number of birds observed per set during line setting operations.

Despite periods where elevated seabird observations were recorded, no clear linear relationship was evident between the total number of seabirds observed during individual sets and the occurrence of reported seabird mortalities. Most reported mortalities occurred during sets where moderate numbers of seabirds were present (approximately 40–50 birds observed), suggesting that factors beyond absolute seabird abundance influenced interaction risk.

Seabird behaviours recorded during setting operations included qualitative categories such as “flying”, “following the vessel”, “foraging” and “attacking” baited hooks (**Figure 3.5**). Observationally, fewer seabirds were recorded during deployments using Tori Line B compared with Tori Line A across several behaviour categories. However, substantial variability was present within the dataset and no formal statistical comparison between tori line configuration and seabird behaviour categories was undertaken.

The observational variability present in the dataset possibly reflected differences in fishing practices, operator deployment techniques, crew familiarity with mitigation systems and vessel-specific configuration characteristics. Factors including tori line attachment height, stern layout, line-setting speed, prevailing weather conditions and deployment stability influenced the effectiveness of mitigation methods including aerial coverage and seabird deterrence during fishing operations.

Collectively, the results possibly suggest that interaction risk was influenced by a combination of seabird behaviour, tori line aerial performance, deployment stability, fishing operator skill and prevailing environmental and operational conditions, rather than seabird abundance or mitigation device configuration alone.

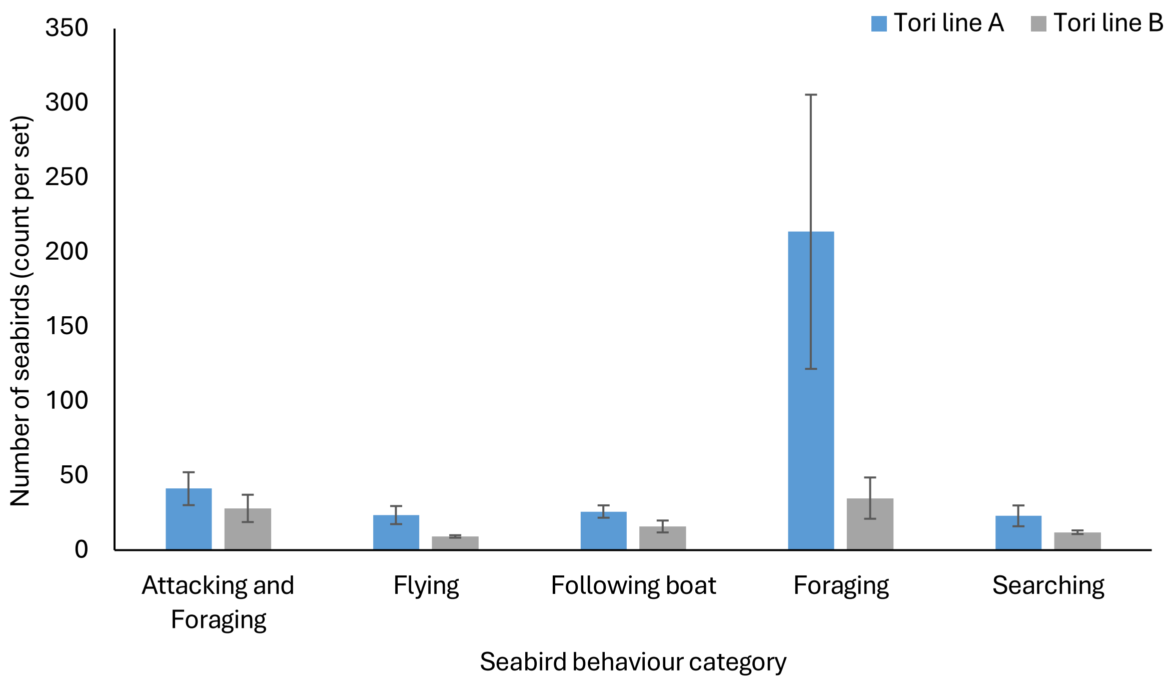


Figure 3.5 Mean observed seabird abundance by behaviour category during line setting across all participating vessels. Behaviour categories represent increasing levels of interaction risk, from transiting birds (flying) through to direct engagement with baited hooks (attacking and foraging), as defined in the Methods section.

Collectively, these observations highlight the complexity of interpreting seabird attendance and interaction risk within operational fishing environments. As discussed previously, the distribution of seabird observations across lunar phases likely also reflects the timing and concentration of fishing effort during preferred fishing periods rather than a direct ecological response to lunar phase alone.

Observationally, fewer seabirds were recorded around deployments using Tori Line B compared with Tori Line A across multiple behavioural categories. While the operational variability within the dataset limits the extent to which this pattern can be attributed solely to tori line design, the result suggests that differences in aerial performance, streamer stability and deployment behaviour may influence seabird attendance around vessels during setting operations.

The effectiveness of mitigation deployment was also influenced by a range of operational factors including vessel configuration, attachment height, deployment technique, prevailing weather conditions and fishing operator experience. These interacting variables highlight the importance of adaptive mitigation approaches that maintain effective aerial coverage and deployment stability under varying fishing conditions.

3.1.6 Seabird interactions and fatalities

Across the trial period, 11 seabird interactions were reported, resulting in 10 seabird fatalities. All fatalities were reported by a single participating vessel, with no fatalities recorded by other trial vessels. Fatalities were concentrated during April–May 2022.

Following this cluster of interactions, a targeted review of tori line performance was undertaken with the vessel in Bermagui, NSW. Modifications were made collaboratively with the vessel operator to both tori line configurations to improve deployment performance during setting operations. These refinements primarily involved increasing drag within the tori line system, which improved aerial extent, streamer coverage and overall deployment stability under operational fishing conditions. The modifications improved the consistency of aerial protection over baited hooks during line setting operations. A summary of this review was provided to AFMA and the project steering committee and is included in Appendix 3.

3.1.7 Tori line performance and aerial extent

Seabird fatalities were recorded across multiple reported tori line aerial performance categories, including deployments classified by crew as “good”, “medium” and “not assessed” (

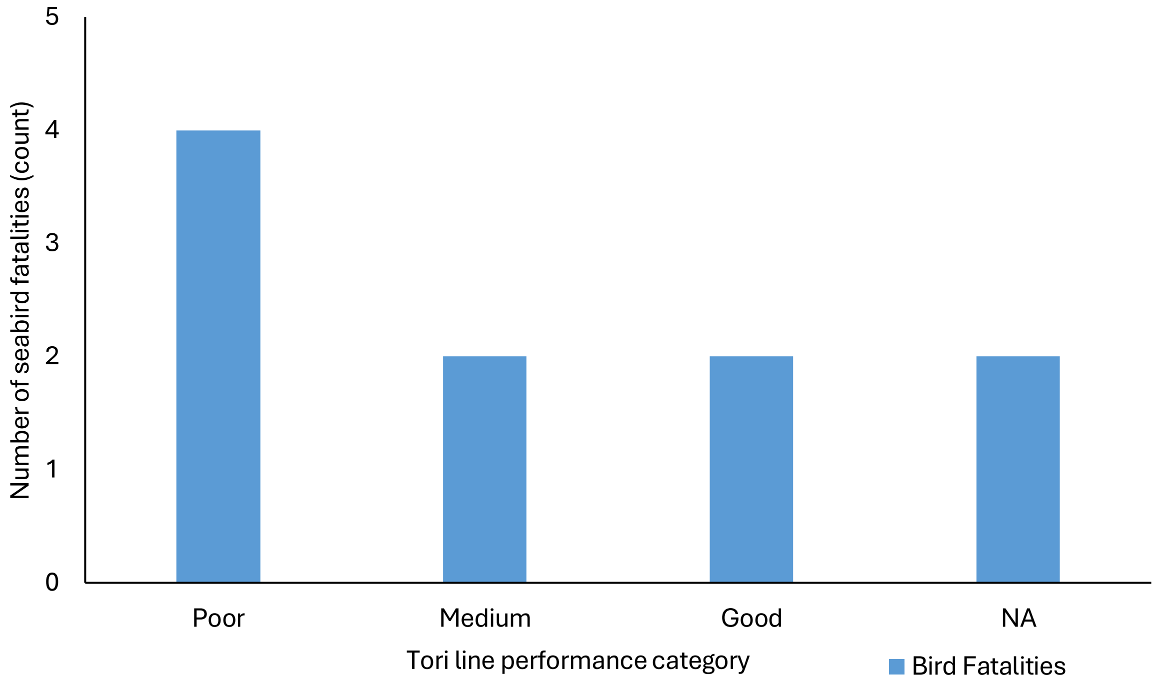


Figure 3.6). As a result, no clear relationship could be confidently established between crew-assessed aerial performance categories and reported seabird fatalities within the operational dataset.

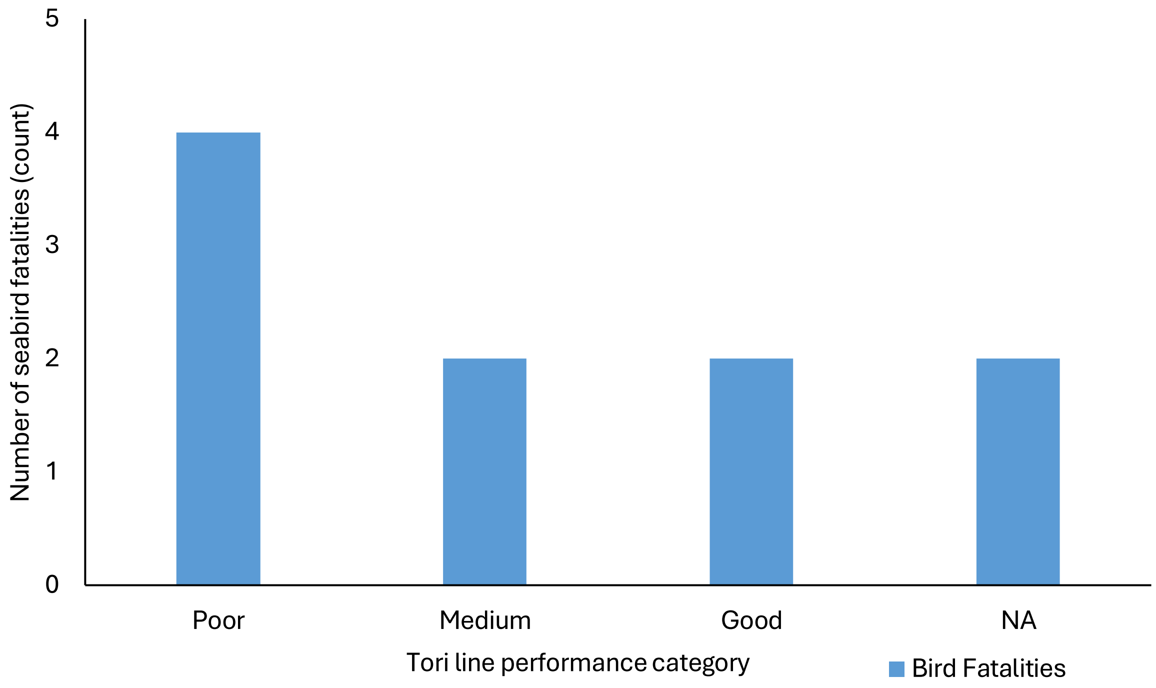


Figure 3.6 Relationship between tori line performance categories and observed seabird fatalities during line setting. Performance categories are based on observer-assessed aerial extent, streamer coverage, line stability and effectiveness in reducing seabird access to baited hooks, as defined in the Methods section.

Notably, the reported mortality cluster occurred during deployments using Tori Line A under wind conditions of approximately 15–20 kts. While crew assessments during this period generally classified tori line performance as "good", subsequent operational review suggested that the lighter streamer material used in the Tori Line A configuration may have reduced deployment stability and effective seabird deterrence under stronger wind conditions despite maintaining apparent aerial extent.

These observations highlight the limitations associated with subjective crew-based aerial performance assessments and suggest that factors beyond estimated aerial extent alone, including streamer behaviour, deployment stability and environmental conditions, may influence mitigation effectiveness during commercial fishing operations.

Average reported aerial extent during the trial was 58.75 m for the Type A tori line (monofilament backbone) and 54.75 m for the Type B tori line. These values were below the AFMA recommended minimum aerial extent of 75 m for vessels under 35 m in length. However, reported aerial extents were based on crew estimates rather than direct measurement and are therefore subject to uncertainty.

During targeted post-trial measurements conducted on one project vessel, aerial extents of approximately 100 m were achieved for the Type A tori line and 75 m for the Type B tori line following modification of the trailing line configuration. These modifications involved removing a substantial portion of the trailing line and replacing it with conical funnels to increase drag at the water surface, resulting in improved aerial extent, streamer coverage and deployment stability.

3.1.8 Comparative performance under varying wind conditions

Reported tori line performance classifications (“excellent”, “good”, “medium”, “poor”) represented crew-based operational assessments that integrated multiple observations including aerial extent, streamer coverage, deployment stability, alignment over the hook entry area, seabird deterrence behaviour and overall effectiveness in limiting bird access to the interaction zone.

Performance assessments varied across wind strengths and tori line configurations (**Figure 3.7**). However, substantial variability within the dataset and limited observations across some wind categories prevented clear conclusions regarding whether one tori line configuration consistently outperformed the other under different wind conditions.

The observations suggest that tori line effectiveness may be influenced by interactions between streamer characteristics and prevailing environmental conditions. For example, heavier streamer materials may provide greater deployment stability and maintain aerial coverage under stronger wind conditions, whereas lighter streamer materials may provide increased movement and visual deterrence during lighter wind conditions.

These observations indicate that mitigation effectiveness may depend on achieving an appropriate balance between stability and streamer movement across varying operational environments rather than a single configuration performing optimally under all conditions.

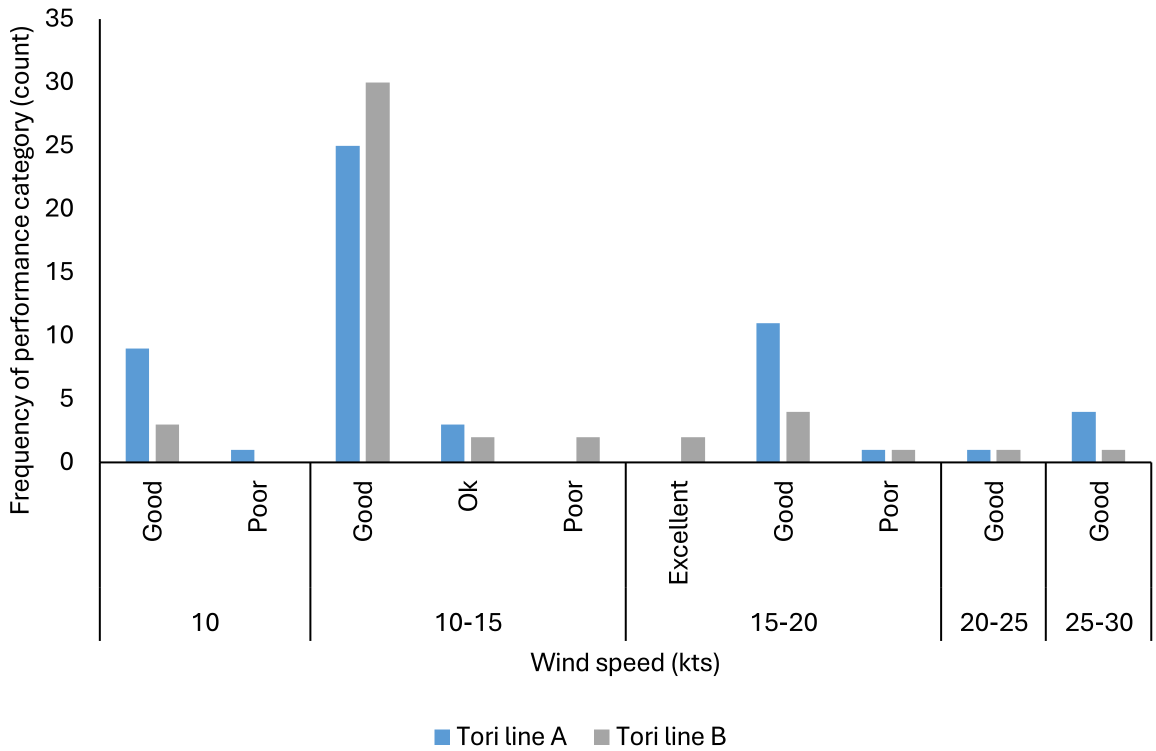


Figure 3.7 Tori line performance under varying wind conditions observed during the trial period, demonstrating the influence of environmental conditions on aerial extent, line stability and coverage of the seabird interaction risk area. Wind speed categories are based on measured wind speeds (knots) recorded during line setting operations.

3.2 7m streamer spacing trial

Five vessels participated in a short-term trial of a prototype tori line with 7 m streamer spacing to explore whether this configuration provided operational or performance benefits relative to existing tori lines used in the ETBF with 5m streamer spacing. This component was included within the broader project as a low-cost extension activity.

The trial also provided an opportunity to evaluate the use of detachable streamers as a potential design enhancement. Detachable streamers were considered beneficial for improving ease of deployment, maintaining streamer effectiveness, and allowing streamers to be added or removed in response to observed seabird behaviour as identified in Section 3.1.5. At the time of the trial, detachable streamers were used by only one vessel in the ETBF.

Participating vessels were based in southern ports to ensure deployment in areas of elevated seabird interaction risk. All vessels fished between latitudinal bands of 30°S–35°S or 35°S–40°S. Short-term scientific permits were issued for the period 28 November 2024 to 17 February 2025. Trial timing coincided with annual vessel maintenance periods and holiday leave for deck crew, which limited fishing effort and constrained data collection to qualitative assessment only. The duration of the trial was also influenced by the need to align with completion of other project components and report preparation.

Post-trial interviews were conducted with project Fishing Masters and/or vessel owners to capture operational feedback relevant to industry. Key themes arising from this feedback are summarised below.

3.2.1 Streamer colour coding

Fishing Masters consistently identified colour coding of streamers as a useful feature to indicate correct attachment positions along the tori line. Colour coding enabled deckhands with limited prior experience to deploy the tori line correctly, relying on visual cues rather than detailed instruction.

Some fishers reported that heat-shrink tubing used to secure coloured markers to the Dyneema backbone detached over time (**Figure 3.8**). In response, secondary markers were added using paired mini crimps positioned either side of the heat-shrink tubing to maintain alignment. Future design improvements could include dyeing the Dyneema backbone at fixed intervals or incorporating permanent markings during manufacture. This was identified as an important design consideration for development of a commercially available, off-the-shelf tori line system.

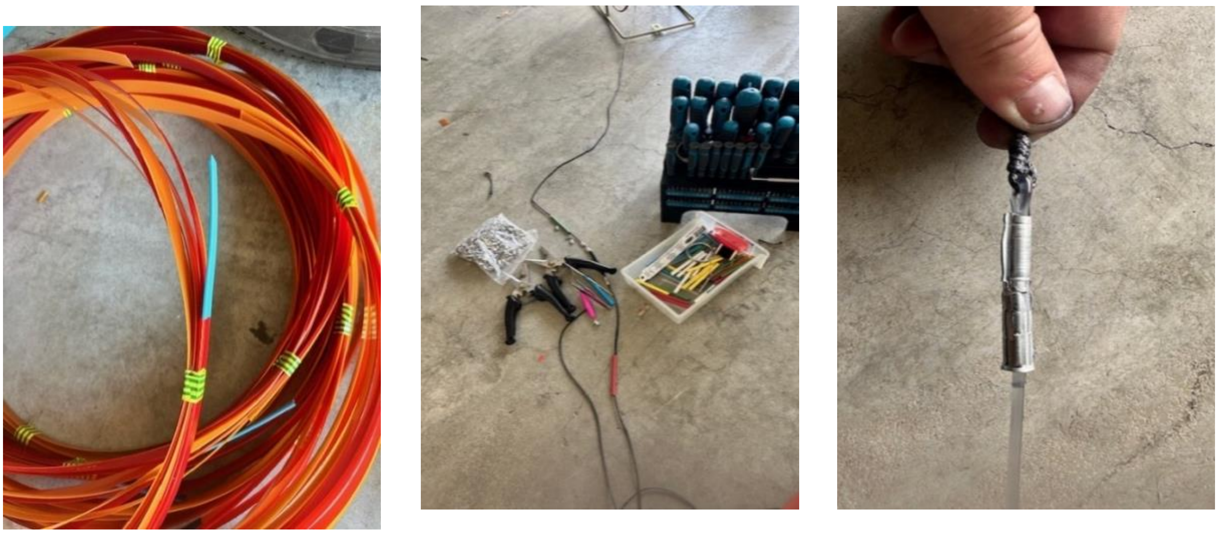


Figure 3.8 Tori line construction components used during the trial, including coloured streamer materials (left), Dyneema backbone with heat-shrink reinforcement and crimping (centre), and looped attachment system for streamer connection (right). These components were designed to improve durability, reduce line twist and support consistent deployment under operational conditions..

3.2.2 Streamer configuration

Each streamer was fitted with either one of two streamers (**Figure 3.9**) to enhance visibility and generate unpredictable movement. Streamers were constructed from heavy-duty pallet strapping in high-visibility colours, consistent with materials used during the 3.5 m streamer spacing trial in combination with lighter box strapping.

While paired streamers performed satisfactorily, several Fishing Masters suggested that a single streamer constructed from the heavier pallet strapping would reduce overall system weight while maintaining or improving movement. Opportunistic deployment of single-streamer streamers during an unrelated fishing trip indicated increased flexibility and movement relative to paired streamers.


Figure 3.9 Comparison of streamer materials used in the trial, including paired streamers (left) and single-strand pallet strapping (right). Both configurations provided effective visual deterrence in varying wind conditions.

3.2.3 Detachable streamer connection points

A commonly identified limitation of existing tori line designs is the need to store streamers permanently attached to the backbone, often within bins, wheels or drums. This can contribute to tangling during deployment and premature degradation of streamer material.

All participating Fishing Masters reported that detachable streamers improved ease of storage and deployment. The preferred attachment method involved a small shark clip connected to a loop of streamer material via a cable tie or small stainless-steel ring (**Figure 3.10**). Fishers noted that additional reinforcement, such as heat-shrink tubing, may improve durability at connection points. Paired streamers were secured using welded heat-shrink to reduce wear.

Figure 3.10 Single strand pallet strapping fixed in place with zip ties, attached to stainless steel ring and shark clip for ease of attaching.

3.2.4 Trailing line configuration

A trailing line length of 200 m was used as the drogue component of the tori line system replacing a cone placed at 100 m. No complaints or hook-ups were reported on the trailing line, despite initial concern that the join between the Dyneema backbone and trailing line could represent a tangling risk. This join was sealed using heat-shrink tubing, which may have contributed to reduced snagging.

The only reported entanglement during the trial occurred during initial deployment on one vessel, when streamer length had not been adjusted resulting in contact with a beacon. Following correction of streamer length, no further incidents were reported.

3.2.5 Modifications during the trial

Fishers were given flexibility to modify the tori line configuration to suit individual vessel layouts and operating styles. All tori line kits were supplied with a nominal 10 m distance to the first streamer and sets of streamers in 8 m, 7 m and 6 m lengths spaced 7 m apart.

Two vessels reduced the distance from the vessel to the first streamer to approximately 5 m. All vessels trimmed the first streamer to prevent contact with the mainline during setting. Even brief contact with the mainline was considered sufficient to dislodge live bait from hooks, making this modification consistent with common practice in existing tori line configurations.

3.2.6 Tori line performance and stability

Over the limited duration of the trial, all Fishing Masters reported that the 7 m streamer spacing tori line deployed and operated effectively across a range of weather conditions.

Despite some inconsistencies in reporting due to language barriers, aerial extent was consistently estimated to exceed 60 m and was often reported to reach approximately 90 m under favourable conditions.

These estimates are consistent with aerial extents observed for the 3.5 m streamer spacing tori line and support the view that simpler, lighter tori line designs can achieve effective aerial performance. Video footage provided by Fishing Masters indicated that the reduced number of streamers contributed to improved stability alongside the mainline, maintaining a deterrent effect for seabirds during the initial phase of gear deployment.

3.2.7 Seabird observations and interactions

No seabird mortalities were reported by participating research vessels during the short-term trial. Overall, the number of seabird observations was low, with a maximum of approximately 30 birds observed during any single set. Shearwaters were the dominant reported seabird group, occurring at an approximate ratio of five Shearwaters to each Albatross observed. Given the timing of the trial near the end of the Shearwater migration period, this pattern was expected.

Reported seabird behaviour was often described as “foraging” or “attacking,” with responses to the deployed tori line recorded as either “afraid” or “ignoring.” While these descriptors are subjective, observations of birds exhibiting avoidance behaviour suggest an observable response to the visual deterrent. Instances where birds ignored the tori line highlight the need for further investigation to better understand drivers which may assist in further improving the efficacy of tori lines.

3.3 Tori line storage

Observations from the sea trials and industry consultation indicate that, under current mandated specifications, tori lines can be challenging to deploy and retrieve consistently. Common issues reported by fishers included streamers tangling or twisting during deployment, streamers catching on beacons or floats attached to the mainline, and difficulties associated with storing tori lines between sets. Safety considerations during deployment and retrieval were also noted, particularly when lines were not retrieved in a controlled manner.

While existing tori line configurations have demonstrated effectiveness as a seabird mitigation measure, fishers reported that the volume of streamer material used in construction can contribute to sagging and instability under unfavourable environmental conditions. This increases the likelihood of tangling and requires careful handling during retrieval to ensure the line can be redeployed effectively on subsequent sets. Tori line storage solutions observed across the fleet ranged from simple reels and drums to purpose-built, engineered storage systems, with varying degrees of effectiveness in reducing tangling and facilitating safe handling (**Figure 3.11**)

Figure 3.11 Engineered tori line storage systems used within the ETBF, illustrating alternative approaches to storing and deploying tori lines. Improved storage systems reduce tangling, enhance deployment efficiency and support safer handling during fishing operations.

During the project, a range of options for improving the efficiency, effectiveness and safety of tori line systems were assessed, including alternative backbone materials, different streamer attachment arrangements, streamer material types, streamer spacing, drogue (trailing line) materials and storage configurations. Results from both trials and industry feedback reinforced that consistent deterrent performance depends on maintaining a well-configured and well-maintained tori line, with a full complement of functional streamers, positioned to provide consistent coverage of the seabird interaction risk area astern of the vessel.

Fishers also highlighted the importance of adapting tori line configurations to suit vessel-specific characteristics and prevailing environmental conditions, within the constraints of existing regulations. Adaptive approaches identified during the project included carrying multiple tori line configurations demonstrated to perform effectively under different operating conditions (e.g. strong winds or rough seas), as well as modifying individual components of a single line in response to changing seabird presence, such as adjusting streamer number, spacing or trailing material. In addition, engineered solutions that allow more precise control over tori line placement relative to wind direction, or enable adjustment of the line's position while deployed, were identified as practical mechanisms for maintaining effective coverage of the fishing gear. These observations provide a direct transition to consideration of adaptive tori line configurations assessed in the following section.

3.4 Adaptive tori line system

Consistent with the objectives outlined in the Methods section, the project sought to develop an adaptive tori line system capable of incorporating the full suite of tori line improvements identified throughout the research.

The underlying intent was to enable fishers to adjust key elements of tori line configuration such as placement, deployment angle, retrieval method and line handling in response to changing environmental conditions, seabird behaviour and vessel-specific operating characteristics.

While the project applied for funding for proof-of-concept testing of the adaptive tori line system, this was not supported. Nevertheless, the engineering design phase was completed in full, providing a comprehensive adaptive system concept that demonstrates how all elements of a tori line could be adjusted in an integrated and safe manner.

The full engineering design report prepared by AMC Search is commercially sensitive. Anyone interested in this report is encouraged to contact AMC Search or Tuna Australia. Details are provided in Appendix 4.

The report includes technical drawings and rotating three-dimensional models in CAD output developed in accordance with the project design brief. Although specific design details are treated as commercial-in-confidence, the drawings represent a complete and replicable "blueprint" that can be manufactured by marine engineering and fabrication businesses. This was considered particularly important given the geographic spread of tuna longline fishing vessels and the need for locally supported fabrication and maintenance.

Figure 3.12 Adjustable tori line pole and gearing system developed by AMC Search, enabling modification of deployment angle to maintain optimal aerial extent and coverage of the seabird interaction risk area under varying environmental conditions.

Key elements of the adaptive tori line design with demonstrated potential benefit to industry include:

1. Material selection and durability

   The system is designed using marine-grade materials selected for longevity and corrosion resistance, including 316-grade stainless steel for the tori pole and drive components, and silicone bronze for the worm gear and cone clutch (**Figure 3.12**). Silicone bronze was selected for its self-lubricating properties and resistance to marine corrosion.

2. Power and drive system

   The design proposes the use of a 1250 W electric motor and gearbox adapted from a recreational anchor winch application. A Savwinch motor was recommended due to its availability, cost-effectiveness, proven service life and suitability for the relatively low power demands associated with tori line deployment and retrieval.

3. Automated retrieval

   Automated retrieval of the tori line via a cassette drive system is incorporated to maintain line condition and reduce manual handling. This feature has the potential to reduce repetitive strain injuries and minimise the risk of injury associated with free-spinning components during retrieval.

4. Operator safety

   Movement of the tori pole under load was identified as a potential safety risk during design development. This risk is mitigated by a self-locking worm gear, which prevents back-driving of the handle and eliminates the possibility of uncontrolled rotation causing operator injury.

5. Cost and accessibility

   The estimated material cost for fabrication of the complete adaptive system was approximately AUD $7,500. Due to the modular nature of the design, the adaptable tori pole componentry alone could be fabricated for approximately AUD $3,500. This compares favourably with the cost of fixed, deck-mounted standalone tori poles, which typically require permanent deck modifications, installation of stays and limited relocation options.

6. Operational flexibility

   A simple flag-pole style pulley system is incorporated to allow rapid changing of tori lines. An attachment point is also included for a recovery line, providing a safeguard against loss of the tori line if it becomes entangled with fishing gear during deployment.

Although the adaptive tori line system was not fabricated and trialled at sea, the completed engineering design demonstrates the feasibility of an integrated, adjustable system capable of addressing many of the deployment, safety and performance limitations identified during sea trials and industry consultation. The design provides a clear foundation for future 'proof-of-concept' testing and incremental improvement and adoption by industry.

3.5 Improving crew safety by revising the design and deployment of line weighting

3.5.1 Shortened safety leads

Five vessels initially agreed to participate in the sliding (shortened) safety lead trial. As with other sea trial components, COVID-related disruptions delayed commencement due to manufacturing and delivery constraints. During this period, one project vessel exited the fishery, resulting in four vessels completing the trial.

At the completion of each set, Fishing Masters recorded vessel-level setting details and qualitative observations of safety lead performance using a standardised data collection form (Appendix 5).

Across the trial period, 563,538 hooks were deployed using shortened safety leads. The mean number of hooks per set was 2,162, with vessel-level variation ranging from 1,689 to 3,264 hooks, reflecting differing operational strategies. Safety lead placement was determined by Fishing Masters within regulatory limits, with most leads positioned 1.5–2.0 m from the hook. The maximum recorded distance was 2.5 m, and no vessel deployed the lead at the maximum permitted distance of 3.5 m.

While sink rates were not instrumentally measured during the sea trials, positioning the safety lead closer to the hook could potentially improve sink performance across all deployments. Quantitative sink-rate performance of this device is addressed in the companion project FRDC 2021-078. In trials, modified 60 g sliding lumo leads were positioned 1 m from the hook, and compared against a standard 60 g swivel placed 3.5 m from the hook. The results showed lumo leads sank slower than standard swivels by 0.151 m/s ($p < 0.005$) to 5 m depth, and 0.178 m/s ($p < 0.0005$) to 10 m depth. At the end of the 75 m tori line, depth was not significantly different between lumo leads and standard gear.

While standard gear sank faster than lumo leads, it is critical to highlight that setting conditions were different between the days trials were performed. Standard gear was set with a faster shooter speed, slower vessel speed, and in the same direction of the current, while lumo leads were set against the current. Results should therefore be treated with caution.

In addition, the behaviour of shortened safety leads under load was assessed through controlled flyback simulations conducted at the Australian Maritime College (AMC). Results from those simulations, along with comparative testing of alternative line-weighting approaches including Procella hooks and the Yamazaki double-weighted branchline (DBL), are presented in a subsequent Results section (see Section 3.9).

Bait use reflected vessel-specific fishing strategies, with squid-only and squid–pilchard mixtures being the only bait types reported. All recorded flyback events occurred during shots using squid-only bait. A chi-square analysis identified an association between bait type and reported flyback occurrence ($p = 0.002$).

However, given the operational nature of the dataset and the relatively limited number of observed flyback events, the result should be interpreted cautiously.

While the observations suggest that bait type may influence operational conditions associated with flyback risk, the underlying mechanism cannot be determined from the present study. Factors such as shark abundance, fishing location, target species, environmental conditions and fishing practices may also contribute to the observed pattern.

Nevertheless, the operational trend observed is consistent with industry experience that larger dead baits such as squid may attract increased shark activity, potentially increasing the frequency of bite-offs and subsequent recoil events. Further targeted investigation would be required to determine the relative contribution of bait type and associated operational factors to flyback risk.

Table 3.1 Bait types used during the sea trials and number and proportion of sets for each bait type.

Bait type	Number of sets	**Proportion of sets (%)**
Squid only	153	
Squid and baitfish	112	

* Squid–pilchard ratios varied between approximately 75:25 and 90:10.

Overall, 18 flyback events were recorded across 563,538 hooks deployed during the trial period, equating to an approximate flyback incidence of 0.003%. However, flyback events were not evenly distributed across participating vessels. A total of 94.4% (n = 17) (**Figure 3.13**) of all reported flyback events occurred on a single vessel during two consecutive trips undertaken in April–May 2022, with only one flyback event recorded across all remaining participating vessels.

Investigation of the affected vessel identified that safety lead caps had been overtightened, preventing the sliding safety lead from functioning as intended under tension. Once cap settings were adjusted to restore sliding function, no further flyback events were reported on that vessel.

While the low overall frequency of flyback events suggests that the modified configurations performed effectively under most operational conditions, the clustering of events highlights the importance of equipment setup, deployment practices and vessel-specific operational factors in influencing flyback risk.

The operational distribution of flyback events also suggests that factors beyond line configuration alone may contribute to risk, including fishing practices, shark abundance, fishing location, target species, bait type and prevailing environmental conditions. Consequently, the observed outcomes should be interpreted within the context of a commercial fishing environment where multiple interacting variables influence operational performance.

Figures 3.8 to 3.12 illustrate key gear configurations, material innovations and operational outcomes developed and assessed during the project to improve mitigation performance and crew safety.

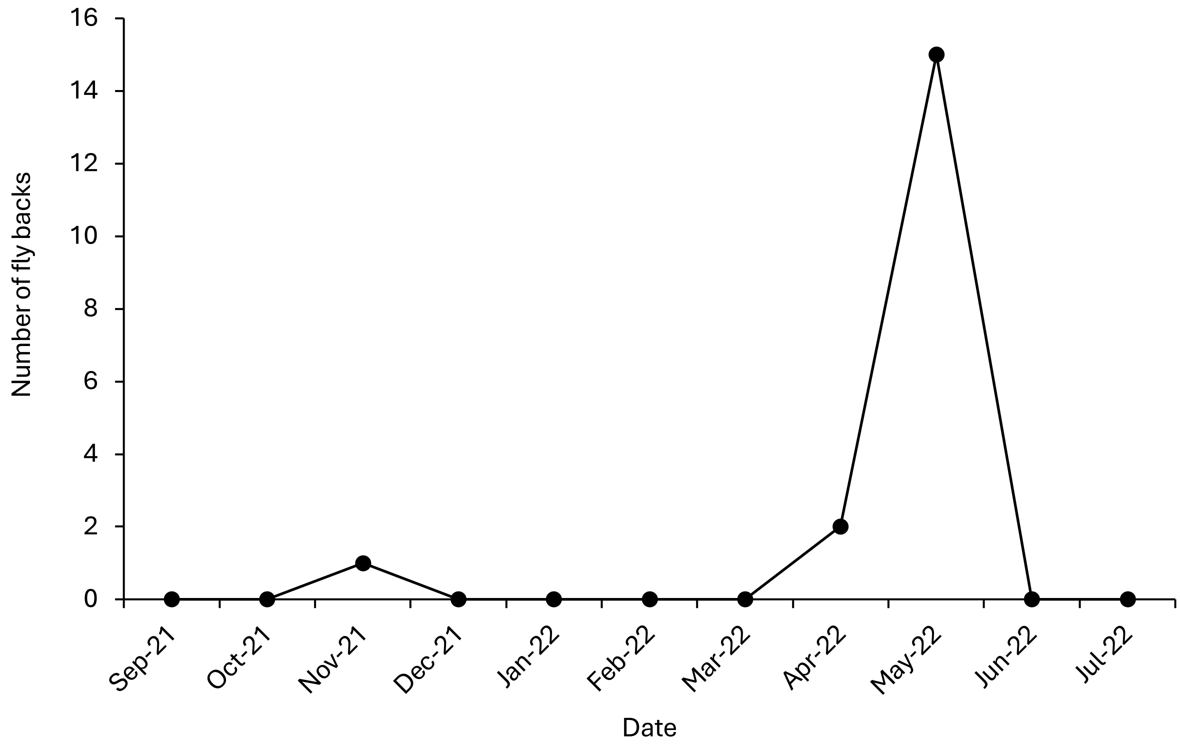


Figure 3.13 Number of flyback events recorded between September 2021 and July 2022 for vessels participating in the shortened safety lead trial. Results are presented as counts over time and demonstrate changes in flyback frequency associated with modified line-weighting configurations under operational conditions.

Recording of bin tangles was inconsistent during the trial. However, qualitative reports indicated low incidence, described as "few," "very few," or comparable to conventional lead swivels. Where numeric values were provided, bin tangles ranged from zero to nine per set, corresponding to rates of 0–0.4% when expressed relative to hooks deployed. Fishers attributed the low incidence of tangles to both the shortened lead design and its placement closer to the hook, which allowed leads to sit clear within bins during branchline coiling and deployment.

Review of written comments and post-trial interviews confirmed strong acceptance of the shortened safety leads and their perceived effectiveness in reducing flyback risk. Fishing Master testimonials describing operational experience with the device are included in the project extension materials, and two Fishing Masters agreed to provide formal testimonials to support broader industry uptake.

Collectively, these results demonstrate that relatively minor modifications to existing line-weighting systems can deliver meaningful improvements in crew safety while maintaining operational practicality.

Building on these findings, the following section examines hook-shielding devices as an alternative and complementary approach to reducing seabird interactions and mitigating flyback risk.

3.6 Assessing hook shield devices under flyback simulation

3.6.1 Hookpod mini

The Hookpod is a commercially available hook-shielding device designed to prevent seabirds from accessing baited hooks during line setting. Although the device is available to Australian longline fishers, it has not been adopted within the ETBF. However, the hookpod is used in some international tuna longline fisheries where seabird interaction rates are often elevated with varying success.

Feedback obtained from ETBF fishers during the project identified several operational factors that have limited industry uptake. These included concerns regarding per-unit cost, additional complexity during setting, compatibility with existing hook bin systems, reliability of the mechanical opening mechanism, and uncertainty around device longevity under repeated commercial use. Fishers also raised concerns about handling efficiency and whether the device would integrate seamlessly with established fishing practices without introducing additional safety or operational risks.

As part of this project, the Hookpod was not trialled under normal fishing operations. Instead, its performance was assessed under controlled and simulated conditions to evaluate device behaviour during flyback scenarios. These simulations were designed to examine how the shielding mechanism behaves when subjected to sudden load release and recoil forces, and whether the device alters the trajectory, velocity or hazard profile of flying components.

Results from the controlled simulation testing are presented in a subsequent section of this report (Section 3.9). These results provide insight into the performance of hook-shielding devices under worst-case conditions and inform comparative assessment against alternative mitigation approaches evaluated in this project.

Overall, while the Hookpod represents a technically credible hook-shielding option and remains commercially available through Hookpod, the combination of operational complexity, cost considerations and integration challenges identified by ETBF fishers has constrained its uptake. These findings reinforced the project’s emphasis on mitigation measures that could be readily integrated into existing fishing systems, minimise additional handling steps, and deliver measurable safety and mitigation benefits without compromising operational efficiency.

3.6.2 Smart Tuna Hook

Although the Smart Tuna Hook has demonstrated technical effectiveness in reducing protected species interactions, it was not progressed to field or simulation testing within this project.

Industry consultation and project scoping identified several practical barriers that have limited uptake of the STH within the Australian tuna longline sector.

Key constraints included the ongoing per-unit cost associated with the single-use shielding domes, concerns regarding cumulative waste generation from discarded caps, and the requirement to purchase and rig specialised hooks rather than using standard longline gear. These factors were consistently identified by industry as significant impediments to routine operational use.

As part of the project, Tuna Australia sourced a limited number of STH units for review and engaged directly with the inventor to assess the feasibility of conducting trials within the ETBF. These discussions confirmed that approximately 6,000 units remained available globally, sufficient for only three to four commercial longline sets and that there were no current plans to recommence commercial production. On this basis, the Steering Committee was advised that the device could not be meaningfully evaluated within the scope of the project.

Accordingly, the STH was not progressed further. While the device remains recognised by ACAP as a best-practice mitigation measure, its limited commercial availability, single-use design and lack of uptake in Australian longline fisheries constrain its practical application under prevailing ETBF fishing practices. These considerations reinforced the project's focus on mitigation approaches that could be trialled, evaluated and refined using commercially available gear with a clear pathway to industry adoption.

3.6.3 Underwater Bait Setter

Despite extensive preparatory work, the proposed Underwater Bait Setter (UBS) trial did not proceed. During project implementation, UBS proponents withdrew their involvement on two occasions. On the first occasion, the proponents withdrew citing insufficient financial resources, while subsequently relocating the device to New Zealand for testing.

In response, the project scope was revised and reprioritised to identify cost savings, alongside additional financial commitments from AFMA and Humane Society International (HSI) to underwrite the full purchase cost of the device. Despite these adjustments, the UBS proponents withdrew again and declined to provide a device for installation and testing on an Australian tuna longline vessel. As implementation of the trial was dependent on UBS proponent participation, this decision prevented delivery of the planned WHS investigation and live-bait trial within the ETBF.

Following withdrawal of the UBS proponents, HSI also removed its funding commitment, as this support was specifically tied to UBS testing and could not be redirected to alternative live-bait research components. As a result, the project plan and budget were revised for a second time, and the opportunity to retain a PhD candidate to support data analysis was lost.

Consequently, no empirical data were generated on the WHS performance or impacts of the UBS when used with live bait in Australian tuna longline fisheries.

Key questions regarding bait survival, handling efficiency, operational practicality and overall efficacy under ETBF fishing practices therefore remain unresolved. These uncertainties represent a significant barrier to industry consideration of the UBS, given the reliance of the fishery on live bait and the operational complexity associated with installing and maintaining stern-mounted hydraulic systems.

The absence of commercial-scale application of the UBS in Australian tuna longline fisheries, outside of limited research contexts, also highlights broader challenges associated with its promotion as a “best practice” mitigation measure. Without demonstrated efficacy under prevailing Australian fishing practices, particularly live-bait operations, industry uptake is unlikely. These considerations informed the project’s decision to prioritise alternative mitigation approaches that could be directly trialled, evaluated and refined within the ETBF.

3.7 Investigating physical protection systems to safeguard crew against flybacks

While improvements to branchline design and line-weighting configurations can substantially reduce flyback risk, results from industry consultation indicate that some fishers are reluctant to move far from established gear configurations and fishing practices that are known to be effective for catching target fish. This necessitates consideration of alternative approaches that provide additional protection for crew while allowing the continued use of standard longline gear.

Over the past decade, a range of personal protective equipment (PPE) options, such as helmets, face shields and chest protection have been trialled informally within the ETBF. However, feedback from fishers highlighted significant practical limitations when using worn PPE in harsh marine environments, including heat stress, restricted movement and reduced visibility. Given the known velocities and impact angles associated with flyback events, PPE may reduce injury severity but is unlikely to prevent impacts altogether. Trials of equipment adapted from motocross and paintball applications further reinforced that worn PPE does not provide a practical or reliable standalone solution for mitigating flyback risk during routine fishing operations.

Industry feedback also indicated that the ability to control the direction and angle of branchlines during fish fighting is a critical factor in reducing flyback risk. Many reported flyback events occur when a hooked fish swims adjacent to the vessel, creating slack in the branchline before sudden re-tensioning due to vessel movement or a change in fish behaviour. In these situations, physical structures that guide or deflect the branchline trajectory, such as bar-type or screen-based systems have the potential to redirect flyback energy towards the vessel hull rather than into the working deck area.

Nevertheless, operational trials provided useful contextual observations regarding the practical application of both systems.

Operators using flyback bars reported no crew injuries associated with flyback events during the trial period, with recoiling terminal gear commonly observed to be redirected toward the vessel hull or away from occupied working areas. Similarly, operators generally viewed flyback screens positively, with some noting perceived operational benefits including reduced sun glare and improved visibility while working on deck. Operators also reported that flyback screens appeared to envelop or intercept recoiling gear, potentially reducing the likelihood of flybacks entering occupied working areas.

While these observations provided useful practical insights, they represented subjective operational experience rather than controlled quantitative assessment. The relatively low frequency of flyback events and the variability in event trajectory, impact location and operating conditions prevented statistically robust evaluation of injury reduction performance under commercial fishing conditions alone. Consequently, although operator feedback suggested potential benefits from both physical protection concepts, further targeted assessment under controlled and repeatable conditions was considered essential.

To address this limitation, the project undertook a series of controlled flyback simulations in collaboration with AMC Search and the Australian Maritime College (AMC) Underwater Collision Research Facility. These simulations were designed to replicate worst-case flyback scenarios under controlled conditions, enabling systematic evaluation of barrier and deflection performance, energy dissipation and projectile trajectories.

Results from two rounds of controlled flyback simulations (Appendix 6 and 7) substantially improved understanding of flyback dynamics and the relative effectiveness of different physical protection concepts. Across all tested configurations, flyback events generated extremely high velocities reaching up to 398 km/hr, confirming the inherent risk posed by recoiling fishing gear and the limitations of relying solely on worn personal protective equipment. Clear and repeatable differences were observed between treatments, particularly where physical deflection or energy-dissipating structures were introduced.

3.7.1 Flyback safety screen

Controlled flyback testing demonstrated that screen-based barrier systems have potential to significantly reduce flyback injury risk, provided they are installed with appropriate tension characteristics. The key finding from the simulations was that screen tension is critical to performance.

Two screen materials (Hortshade LDPE mesh and Spidermesh PVC mesh) were evaluated during proof-of-concept testing. Under loosely hung configurations, both materials were effective at capturing and enveloping recoiling weighted swivels, with no material-specific differences observed in capture performance. Under these conditions, the projectile trajectory was arrested or sufficiently deflected such that the weight did not encroach into the crew working zone or did so with substantially reduced energy.

When installed under taut tension, repeated flyback impacts caused localised damage to both materials. However, Spidermesh was more prone to tearing at the point of impact, whereas Hortshade exhibited greater elastic deformation prior to failure. These observations indicate that installation configuration and tension are the primary determinants of screen performance, with material selection influencing durability and failure mode rather than capture effectiveness.

These results indicate that a loosely tensioned screen, capable of deforming and dissipating kinetic energy is markedly more effective than a rigid or highly tensioned installation (**Figure 3.14**). The findings also provide clear guidance for future design refinement, including the likely need for elasticised stays or flexible frame systems that allow controlled "give" on impact, while maintaining adequate visibility, durability and ease of deployment.

Figure 3.14 Flyback simulation testing of safety screen configurations under controlled conditions, comparing slack and taut screen tension. The slack configuration captured the weighted swivel, while the taut configuration failed under impact loading (circled in red).

3.7.2 Flyback safety bar

Flyback safety bar testing confirmed the strong potential of rigid deflection systems to control branchline trajectory and redirect flyback energy away from crew working areas. Both field installations and controlled simulations demonstrated that bars positioned below and outward of the gunwale effectively altered recoil paths, directing weighted swivels and hooks downwards and towards the vessel hull rather than into the deck space.

Simulation results showed consistent downward displacement of impact locations when a flyback bar was present (**Figure 3.15**), validating the design premise underpinning both vessel-specific installations. The use of larger-diameter tubing increased confidence in durability and longevity, although field experience highlighted trade-offs between robustness, system weight and ease of deployment.

Operational trials on two commercial vessels demonstrated that flyback bars can be integrated into routine fishing operations, but also highlighted practical considerations including manual handling requirements, vessel stability, storage constraints and the need for modular or assisted deployment systems. Despite these challenges, vessel owners involved in the trial expressed a clear preference for physical deflection systems over worn PPE, citing improved perceived safety and reduced reliance on behavioural controls alone.

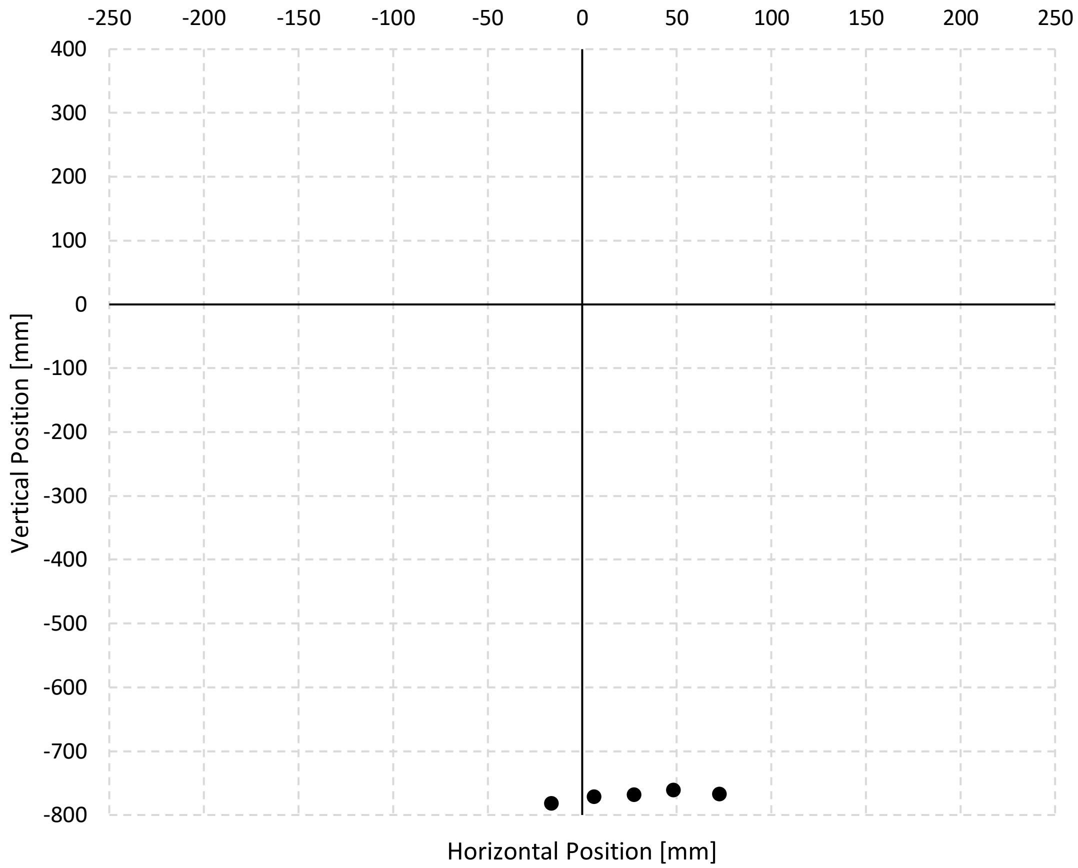


Figure 3.15 Distribution of flyback impact trajectories following interaction with safety bars of different diameters under controlled simulation conditions, demonstrating effectiveness in deflecting recoiling gear below crew working height.

Together, the simulation and operational trial results indicate that physical barrier and deflection systems may provide an additional layer of protection against flyback injuries during commercial longline operations. Under operational conditions, participating skippers and crew generally viewed both flyback screens and flyback bars positively, with operators reporting that flyback bars appeared to redirect recoiling gear away from occupied work areas and toward the vessel hull. Similarly, operators reported that flyback screens appeared to envelop or intercept recoiling gear while also providing ancillary operational benefits such as reduced sun glare and improved deck visibility.

However, the sporadic and highly variable nature of flyback events under commercial fishing conditions limited the ability to collect sufficiently consistent quantitative field data to robustly compare the protective performance of alternative physical protection systems at sea. Consequently, controlled flyback simulations undertaken through AMC Search at the Australian Maritime College provided the primary evidence base for assessing barrier performance, energy dissipation characteristics and recoil trajectory deflection under repeatable worst-case conditions.

Collectively, the operational observations and controlled simulation results support the further refinement and consideration of physical barrier and deflection systems as complementary safety measures alongside gear-based mitigation approaches.

3.8 Operational practicality and factors influencing mitigation uptake

Industry consultation and operational observations undertaken throughout the project indicated that mitigation uptake was influenced by a combination of direct cost, compatibility with existing fishing practices, ease of deployment and perceived impacts on crew safety and operational efficiency. While the project did not undertake a formal economic assessment of mitigation tools, practical operational considerations consistently emerged as important factors influencing the likelihood of industry adoption.

Industry feedback consistently demonstrated that mitigation measures requiring minimal change to established fishing systems, utilise commercially available components and avoiding additional handling complexity were generally viewed more favourably by participating fishers.

Gear-based mitigation measures such as modified tori lines, shortened safety leads and adaptive line-weighting approaches were generally regarded by fishers as operationally feasible, particularly where modifications could be implemented incrementally and tailored to individual vessel layouts and condition. In contrast, mitigation tools relying on specialised consumables, proprietary systems or additional operational steps, such as the Smart Tuna Hook and Underwater Bait Setter, were commonly viewed by participating operators as potentially more difficult to integrate into routine commercial fishing operations.

Across multiple project components, fishers identified indirect operational considerations as important factors influencing mitigation uptake. These included additional time for gear preparation and deployment, impacts on bait handling, storage and logistics constraints and increased crew workload. Where mitigation tools introduced additional complexity into routine fishing operations, uptake was generally viewed less favourably, even where potential conservation benefits were recognised.

Importantly, project results also highlighted that mitigation measures have historically been evaluated primarily in terms of reducing protected species interactions, with less explicit consideration of work health and safety outcomes.

Evidence generated through this project, particularly from flyback simulations and operational observations, demonstrated that some mitigation measures can materially alter the occupational risk profile of longline fishing operations. In several cases, fishers reported adopting informal protective measures or adapting fishing practices to manage perceived increases in operational risk.

Findings from the evaluation of physical protection systems, shortened safety leads and adaptive gear configurations suggested that mitigation approaches capable of simultaneously reducing protected species interactions while lowering crew injury risk may provide broader operational value to industry. Participating fishers commonly indicated that measures perceived to reduce the likelihood or severity of serious injury may justify additional operational effort or equipment modification, even where direct financial benefits were difficult to quantify.

Collectively, these observations suggest that mitigation uptake within the ETBF is influenced by a combination of operational practicality, safety considerations, compatibility with fishing practices and conservation outcomes. The findings indicate that flexible mitigation approaches that minimise operational disruption while supporting both protected species and crew safety outcomes are likely to have greater long-term applicability within commercial fishing operations.

3.9 Evaluate mitigation devices and personal protection technology in controlled flyback simulations at the Australian Maritime College (AMC) Underwater Collision Research Facility

Controlled flyback simulations were undertaken at the Australian Maritime College (AMC) Underwater Collision Research Facility (UCRF) to characterise flyback behaviour, velocities and impact outcomes across a range of standard, modified and novel mitigation configurations. Two simulation campaigns were conducted (August 2023 and August 2024), with detailed results reported in Appendix 10 and 11. This section synthesises key findings relevant to the performance of mitigation technologies when a flyback event occurs.

The simulations focused on worst-case scenarios, with flybacks initiated above the waterline to replicate conditions under which the highest recoil velocities have previously been observed. All configurations were initially tested without secondary protection to establish baseline flyback behaviour, followed by testing with physical protection systems where applicable.

3.9.1 Baseline flyback behaviour of weighted lines

Across all baseline treatments, flyback events generated extremely high velocities over very short distances, confirming the severity of the hazard posed by recoiling weighted branchline components.

Standard industry configurations using fixed lead swivels or weighted hooks consistently produced projectile trajectories capable of entering the working deck area at head and torso height.

1. Standard industry configuration

The standard gear configuration, comprising a 60 g weighted swivel positioned 3.5 m from the hook, formed the baseline for comparison. This arrangement produced average flyback velocities of approximately 212 km/h. From a safety perspective, this represents an upper bound of risk, noting that multiple serious injuries have historically occurred in the fishery under this configuration.

2. Weighted swivel – 45 g

This configuration was tested at the request of New Zealand and United States counterparts and replicated higher breaking-strain branchlines with a 45 g swivel positioned 1 m from the hook. This arrangement produced comparatively slower flyback velocities than most other treatments. This outcome is assessed to result from reduced line stretch associated with higher breaking-strain monofilament and the lower mass of the swivel, an observation of potential relevance to international fisheries operating under similar gear specifications.

3. Sliding safety leads – 98 g (100 g @ 4 m equivalent)

The heaviest configuration tested replicated the maximum weight and distance combination mandated by regulators (approximately 100 g at 4 m from the hook). Across all runs, this configuration consistently produced substantially lower flyback velocities than other treatments. While the precise mechanism underlying this effect is not fully understood, it is likely that the increased distance between hook and weight provided a dampening effect during recoil. This unexpected result warrants further investigation but suggests that weight placement may be as influential as weight magnitude in governing flyback dynamics.

Importantly, although recoil velocities for the 98 g sliding safety lead configuration were approximately 50% lower than some lighter-weight configurations, the projectile mass was more than double that of the 45 g treatment. Consequently, lower recoil velocity does not necessarily equate to lower injury severity, as heavier projectiles may still transfer substantial momentum and impact energy during collision with crew or vessel structures. The potential injury outcome from a flyback event is therefore influenced by a combination of projectile mass, recoil velocity, impact trajectory and point of impact rather than recoil speed alone.

In addition, positioning heavier weights further from the hook to maintain bait movement and fishing performance increases the likelihood that the weighted component may become elevated above the water surface during hauling operations, thereby increasing the potential for high-energy recoil events following line failure or hook tear-out.

The simulations further confirmed that relatively small increases in line mass or tension can result in disproportionate increases in recoil velocity and impact energy under some configurations.

These findings reinforce previous experimental work and validate industry observations that flyback injuries often occur with little warning and limited opportunity for evasive action by crew.

3.9.2 Shortened sliding safety leads

Shortened sliding safety leads demonstrated a clear capacity to alter flyback dynamics compared with fixed-weight configurations. Under controlled simulations, the sliding behaviour of the safety lead reduced the effective mass recoiling toward the crew during bite-off scenarios by allowing the weighted component to separate from the recoiling branchline when functioning as intended.

In contrast, during hook tear-out scenarios the weighted component could remain engaged with the recoiling system, resulting in continued flyback events despite reduced recoil velocities under some configurations. The simulation results also demonstrated that incorrect adjustment of the ferrule or retaining cap could prevent the sliding mechanism from functioning correctly, causing the weighted component to recoil during bite-off events. Similar issues were identified during operational sea trials, where overtightened retaining caps were associated with flyback events until adjustments were made to restore proper sliding function.

Within the controlled simulations, projectile trajectories falling below zero on the vertical position axis indicated recoil paths below the approximate gunwale height of the vessel reference point used in the simulator configuration. These trajectories suggest a reduced likelihood of projectile impacts occurring within occupied working areas on deck. When functioning correctly, shortened sliding safety leads demonstrated a greater tendency for recoiling components to fall below this reference line compared with fixed-weight configurations.

While flybacks were not eliminated, the simulations and operational observations collectively support the role of shortened sliding safety leads as a practical risk-reduction measure rather than a complete mitigation. However, industry feedback also indicated that some fishers considered shortened sliding leads to alter branchline stiffness and potentially reduce natural bait movement during fishing operations.

3.9.3 Integrated and double-weighted branchline configurations

The Yamazaki leader configuration, incorporating both fixed and sliding weights, produced velocities broadly consistent with those recorded for 60 g sliding safety leads and 60 g weighted swivels. However, simulations frequently resulted in simultaneous recoil of both weights, with impacts observed to occur on a relatively horizontal plane. Under commercial conditions, this behaviour is likely to increase the probability of both components striking crew, presenting a compounded injury risk.

3.9.4 Procella hook-integrated weighting system

The Procella hook-integrated weighting system was evaluated as part of the project's controlled flyback simulation trial to assess its performance under worst-case tear-out scenarios. Two design iterations were tested, each integrating a 45 g weight directly into the hook shaft, with the intent of meeting ACAP requirements while reducing flyback risk by eliminating separate weighted swivels and sliding components.

1. Procella hook MkI

The first Procella hook iteration produced average velocities of approximately 238 km/h (**Table 3.2**) exceeding those observed for most other configurations. This is assessed to be a consequence of the concentrated mass at the end of the branchline combined with increased monofilament stretch due to the single-piece construction. This version also exhibited unstable flight characteristics, likely due to the non-aerodynamic placement of weight on the hook curvature. Two hooks bent on impact, attributable to the use of "cetacean-friendly" 4.5 mm wire, raising concerns regarding durability and safety under commercial conditions.

2. Procella hook MKII – 62g weighted hook

The second Procella iteration corrected the unstable flight behaviour observed in Procella MkI , possibly in response to redistributing weight more uniformly around the hook curvature (**Figure 3.16**). While this improved aerodynamic stability, it also resulted in the highest velocities recorded across all treatments**.** As with MkI, the hook-weight assembly functioned as a rigid, high-energy projectile, raising significant concerns regarding its suitability for real-world fishing operations without secondary protection.

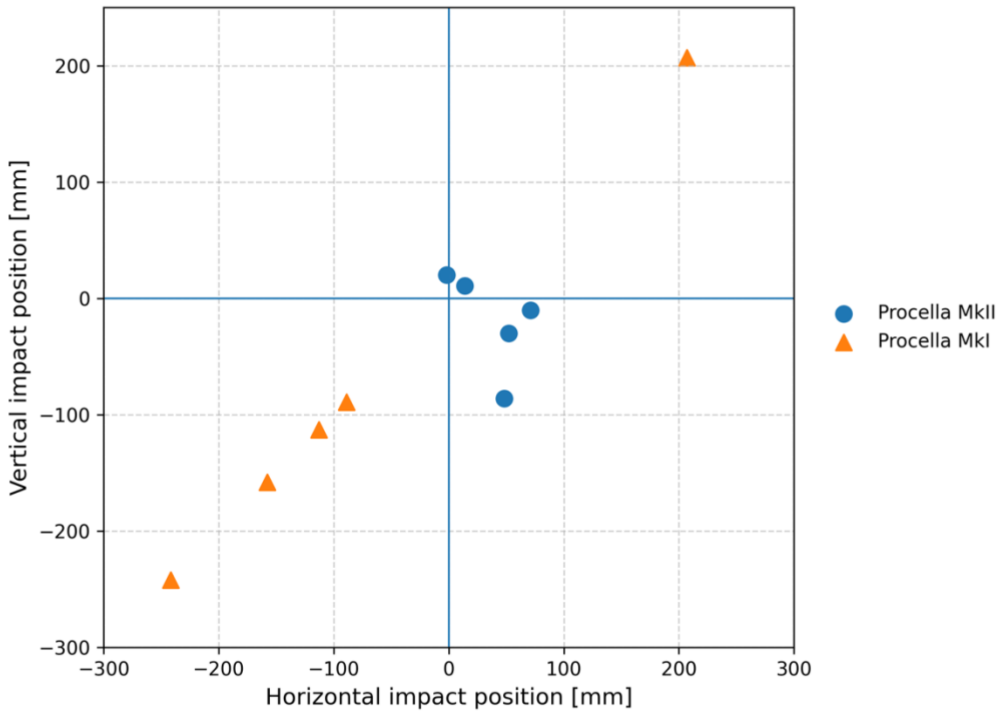


Figure 3.16 Distribution of flyback impact trajectories for Procella MkI and MkII configurations.

Flyback trajectories associated with the Procella configurations are presented in (**Figure 3.16**) and were generally more predictable than those observed with sliding or double-weighted branchlines. As mentioned, both Procella configurations function as a single rigid projectile. Comparison across simulation treatments indicated that, while the Procella system may reduce certain failure modes associated with sliding weights or swivels, it does not eliminate flyback risk under worst-case conditions. In the absence of secondary protection, such as a flyback bar or screen, the resulting trajectories can enter the crew working zone at head and torso height posing a serious injury hazard when uncontrolled.

These findings indicate that the Procella system may offer benefits in terms of sink-rate performance, gear simplification and reduction of some flyback pathways associated with conventional branchline weighting systems. Unlike configurations where weighted components are positioned independently along the branchline, a line break or bite-off involving the Procella system does not result in a weighted component recoiling toward the vessel, thereby eliminating a proportion of potential flyback scenarios.

However, flyback risk is not eliminated entirely, as recoil events may still occur when hooks tear free under tension during hauling operations. The simulations demonstrated that, under such scenarios, hook-integrated weighting systems can still generate high-energy projectiles capable of causing serious injury. Consequently, while the Procella system may reduce the likelihood of some flyback events compared with conventional weighted branchline configurations, it should not be considered a standalone solution for flyback risk mitigation.

As with other branchline-based approaches evaluated in this project, the findings suggest that hook-integrated weighting systems are likely to provide an overall safety benefit when combined with complementary engineering controls capable of redirecting, containing or dissipating recoil energy.

3.9.5 Hook shielding devices

Hook shielding devices were included in the controlled flyback simulations to evaluate their behaviour during tear-out and bite-off events, despite not being designed to influence sink rate or mitigate flyback risk. The Hookpod Mini was selected as a representative of the two commercially available hook-shielding devices.

Simulation results demonstrated that, during high-energy flyback events, Hookpod assemblies frequently failed structurally. In multiple tests, devices either disintegrated on impact or sheared from the hook during flight. As a result, high velocities were recorded for the trailing hook component, while fragments of the shielding device were dispersed upon impact.

These outcomes were not unexpected given the device's design purpose. However, the results highlight important secondary considerations. In a commercial fishing context, flybacks involving hook shielding devices may introduce additional injury risks associated with high-velocity plastic fragments striking crew, particularly where impacts occur at head or torso height. The production of multiple shards also complicates hazard management, as fragment trajectories are unpredictable and may extend beyond the primary recoil path of the hook.

In addition to crew safety concerns, the simulations indicate a potential for increased generation of marine debris during flyback events. Fragmentation of hook shielding devices under load would result in the release of plastic components to the marine environment, particularly where failures occur below the gunwale or over the side of the vessel. This outcome is inconsistent with broader sustainability objectives and was identified by industry as a key concern during consultation.

Overall, the simulation results indicate that while the Hookpod shielding devices may be effective in reducing seabird access to baited hooks during setting, they do not provide secondary benefits in mitigating flyback risk and may introduce additional safety and environmental considerations under worst-case recoil scenarios. These findings reinforce the importance of evaluating mitigation tools not only for their primary conservation function, but also for their performance during failure modes that pose risks to crew and the marine environment.

3.9.6 Flyback safety screens

Controlled simulations demonstrated that screen performance was strongly influenced by installation configuration and material behaviour during impact loading.

Screens installed under taut tension were more susceptible to tearing or rapid loss of protective function following repeated direct impacts, whereas loosely tensioned configurations allowed controlled deformation and energy dissipation during flyback events.

Loose-hung screen configurations provided the most effective balance between impact absorption, projectile containment and structural durability. The results suggest that controlled deformation and energy dissipation are important design characteristics for reducing flyback impact severity and limiting projectile penetration into occupied work areas.

Operational observations also indicated that screen effectiveness may depend on vessel layout, installation geometry and crew working arrangements, highlighting the need for vessel-specific integration and further refinement under commercial fishing conditions

3.9.7 Flyback safety bars

Controlled simulations demonstrated that flyback safety bars functioned primarily as trajectory deflection systems by redirecting recoiling branchline components away from occupied working areas. Both bar diameters tested (48 mm and 62 mm OD stainless steel) were effective in altering projectile trajectories under the simulated configurations assessed.

Unlike screen systems that relied on energy absorption and controlled deformation, flyback bars reduced crew exposure by physically redirecting recoil pathways toward the vessel structure or away from the working deck. The results indicate that bar positioning, installation angle and integration with vessel layout are likely to be important factors influencing protective performance under operational conditions.

Operational observations further suggested that flyback bars may provide a practical engineering control option for some vessel configurations where integration of larger barrier systems is less feasible.

3.9.8 Comparative performance across mitigation approaches

Across all treatments, no single branchline-based mitigation eliminated flyback risk under worst-case conditions. However, the controlled simulations demonstrated that the sliding safety lead configurations incorporating 60 g and fixed 98 g weights produced substantially lower recoil velocities compared with several lighter-weight treatments.

Importantly, lower recoil velocity does not necessarily equate to proportionally lower injury risk. While recoil speeds were reduced, the increased projectile mass associated with heavier sliding safety leads meant that substantial momentum and impact energy could still be transferred during collision events. Consequently, despite reduced recoil velocities, the heavier configurations retained the potential to cause severe or catastrophic injury depending on impact trajectory, impact location and crew proximity during flyback events.

These findings suggest that assessment of flyback risk cannot rely on recoil velocity alone and instead requires consideration of the combined effects of projectile mass, recoil dynamics, weight placement and operational fishing conditions.

Table 3.2 Velocity of line-weighting configurations and hook shielding devices under controlled flyback simulation conditions at the Australian Maritime College. Underwater Collision Research Facility, Launceston, Tasmania.

Configuration type	Min – Max velocity km/hr	Average velocity km/hr	Comments
Standard (60g swivel @3.5m)	211.4 – 215	212.04	
Procella MkI	234.4 – 249.4	238.5	Unpredictable trajectory
Hookpod mini	252 – 323	287	Some readings indeterminable due to Hookpod "shattering" on impact
Safety lead 60g	151.9 – 301.7	194	One "high" result, safety lead tightened too much, didn't slide.
45g swivel @1m	200 – 216	206	US / NZ standard, built on 2.1mm mono
Procella MkII	242 – 249	245.8	
Yamizake	215 – 223	220.4	Measurement of second impact (higher of two weights)
Safety lead 98g	65 – 118	100	"locked" at 4m to replicate 100g @4m from hook

Note- Velocity measured under controlled flyback simulation conditions at the Underwater Collision Research Facility. Values represent mean velocity across replicates.

3.10 Develop a suite of extension products ensuring maximum communications to fishers

This project objective was achieved through the development and delivery of a targeted, multi-channel extension program designed to consider contemporary communication practices and the linguistic diversity of the tuna longline workforce. The approach represented a deliberate shift away from traditional dissemination of text-heavy research materials toward practical, visually engaging and fisher-led communication products.

The extension strategy recognised that fishers increasingly access information through short-form digital media, visual content and peer-to-peer messaging, and that a significant proportion of crew working in Australian tuna longline fisheries do not have English as their first language.

These considerations directly informed the format, tone and distribution pathways of all extension products developed under the project.

A suite of complementary communication products was produced in collaboration with Cultivate Communications, with content focused on practical adoption of research findings rather than technical explanation alone. Products were designed to be modular and adaptable, allowing messages to be delivered across multiple platforms including digital, social media, in-person workshops and hard-copy materials distributed directly to vessels. All products are available on the Tuna Australia and FRDC websites.

Project findings were actively disseminated through industry forums and professional meetings. Tuna Australia presented the research outcomes at industry workshops and FRDC events, and at the Seafood Directions 2024 conference partnered with AMC Search to deliver an interactive "Fish Tank" presentation. This format enabled live demonstration of flyback simulation outcomes and provided a highly effective mechanism for translating complex safety concepts into practical, memorable messages for industry participants.

To support inclusive uptake across multicultural crews, key safety-focused infographics were translated into Tagalog (Filipino) and Indonesian. This ensured that core messages relating to mitigation use and crew safety were accessible to deckhands and crew members who may not engage fully with English-language materials. Feedback from industry indicated that these translated products filled a significant gap in existing extension resources.

Fishers were included throughout the extension process and featured prominently in the communication products, including videos, social media reels and written case studies. Having Fishing Masters and crew articulate the value of safety gear and mitigation practices in their own words was identified as a critical factor in increasing credibility and supporting behavioural change.

Collectively, the extension products developed under this project significantly broadened the reach and accessibility of research findings. By combining modern communication formats, multilingual resources, fisher advocacy and cross-promotion through industry and partner channels, the project met its objective of maximising communication to fishers and strengthening the pathway from research outcomes to on-deck adoption.

A summary of the extension products developed, their purpose and distribution channels is provided in **Table 3.3**. Noting that a full description of extension materials will be provided later in the report.

Table 3.3 Summary of extension products developed, including format, content, target audience and intended outcomes.

Product	Description	Target audience	Intended outcome
2.5-minute project video	Provides an overview of Research project outcomes from 2020-041 2021-078 highlighting partnerships with fishers and researchers, and real-world impacts of the research findings and safety gear.	Tuna Australia website, social media	Improve mitigation application Reduce crew exposure to safety risks Support uptake of safer gear configurations Inform management and policy settings Strengthen evidence-based decision-making Enhance crew training and capability
3 x infographics	Outcomes describing safety improvements in three languages	Tuna Australia website, social media, hardcopies shared with Fishing Masters and fishers	Support industry-wide adoption Contribute to international guidance
7 x social media reels 30 seconds each	Project overview, collaboration, improvements and beneficiary statements	Tuna Australia website, social media	Improve operational safety
Dedicated website page	Housing all research outputs with downloadable content	Tuna Australia website with YouTube links	
Website article	Overview of project outcomes	Tuna Australia website	

Collectively, these extension products are intended to support the adoption of mitigation practices while reducing work health and safety risks under operational fishing conditions.

Extension materials can be found on the FRDC Website - **FRDC Project Page 2020-041** or on the Tuna Australia web page for the project - **Improving the effectiveness, efficiency and safety of mitigation tools for protected species interactions in the Eastern Tuna and Billfish fishery**.

4. Discussion

This project was undertaken to improve the effectiveness, efficiency and safety of protected species mitigation tools used in the Eastern Tuna and Billfish Fishery (ETBF), with a particular emphasis on addressing work health and safety (WHS) risks while maintaining strong conservation outcomes. In doing so, the project deliberately assessed mitigation tools not only on their capacity to reduce seabird interactions, but also on their operational practicality, safety performance and likelihood of consistent uptake by industry. The project findings are discussed in context of the original project objectives and places them within an operational, management and policy context relevant to the ETBF and similar longline fisheries internationally.

4.1 Reframing "effective mitigation" to include crew safety and operational reality

(Objectives 1, 2 and 3)

The results of this project reinforce that effective protected species mitigation cannot be assessed solely through gear performance, and in particular, metrics such as sink rate or aerial extent for seabird mitigation. While these parameters are important, the project findings demonstrate that some mitigation tools assessed increase operational complexity or expose crews to elevated WHS risks and have the potential to undermine both safety and long-term compliance. This is particularly relevant in fisheries such as the ETBF, where protected species (particularly seabird) interaction rates are already low by global standards, and incremental improvements must be achieved without introducing disproportionate safety risks.

The project confirms that several commonly promoted mitigation approaches increase the amount of stored kinetic energy within longline systems and elevate the severity of recoil events during line failure. From a WHS perspective, this represents an unacceptable trade-off if alternative configurations can deliver comparable protected species mitigation with materially lower injury risk. As such, the project supports a more holistic definition of "effective mitigation", one that explicitly integrates crew safety, ease of use and operational efficiency alongside conservation outcomes.

4.2 Tori lines: performance depends on stability, usability and adaptability

(Objectives 1, 2, 5 and 7)

The evaluation of alternative tori line configurations highlights that performance is influenced by wind strength, sea state and vessel configuration. Noting small sample sizes in high wind categories. While all tori lines trialled provided seabird deterrence when correctly deployed, the consistency of aerial coverage and ease of handling varied markedly between designs and operators.

Practical issues reported by crews including tangling, inconsistent aerial extent, interference with fishing gear, and storage and redeployment difficulties were anecdotally shown to have direct implications for both safety and mitigation effectiveness.

These findings suggest there are limitations associated with relying solely on strict standardisation of tori line design to achieve consistent seabird mitigation outcomes across highly variable commercial fishing environments. The project results demonstrated that mitigation effectiveness was influenced by multiple interacting factors including vessel configuration, deployment stability, environmental conditions, fishing practices and operator skill.

Consequently, the project supports consideration of more adaptive approaches to seabird mitigation management in which vessels are equipped with tori line systems capable of being adjusted to prevailing operational and environmental conditions while maintaining effective protection of the seabird interaction zone. The development of detachable streamers, simplified streamer arrangements and adaptive deployment options represents a pathway toward improving operational practicality, deployment consistency and mitigation performance without unnecessarily increasing operational burden or crew safety risk.

Importantly, the project observations suggest that simpler and more stable tori line systems may provide comparable seabird deterrence to existing configurations under some operational conditions, while also reducing handling complexity and improving deployment safety. These findings have direct relevance to Objective 5, which assessed deployment and storage options, and Objective 7, which focused on extension and communication approaches to support practical uptake and operator implementation within the ETBF.

The project findings further suggest that adaptive mitigation approaches are likely to be most effective when accompanied by appropriate accountability and verification mechanisms, including electronic monitoring systems capable of independently assessing seabird interactions and operator performance at the individual vessel level. Within such a framework, responsibility for achieving seabird interaction outcomes shifts increasingly toward demonstrated operational performance rather than sole reliance on compliance with fixed protected species mitigation equipment specifications.

Collectively, the findings indicate that combining adaptive mitigation practices with independent monitoring and operator accountability may provide a more effective pathway for simultaneously improving seabird conservation outcomes, operational practicality and crew safety within commercial longline fisheries.

.

4.3 Line weighting: sink rate alone is an incomplete performance metric

(Objectives 1, 2 and 3)

One of the most significant findings of this project is the relationship between line weighting configuration and flyback injury risk.

Controlled flyback simulations undertaken by the Australian Maritime College demonstrated clear differences in recoil behaviour across branchline configurations, with the 98g fixed sliding safety lead (SSL) configuration producing substantially lower recoil velocities than alternative configurations tested. This represents an important finding in the context of work health and safety, as reduced velocity is directly associated with lower kinetic energy during flyback events.

However, impact severity cannot be assessed on velocity alone. From a physics perspective, both velocity and mass contribute to the outcome of a flyback event. While kinetic energy increases with the square of velocity, the mass of the recoiling object contributes to momentum and the force transferred on impact. As a result, heavier components, even when travelling at lower velocities, still present a significant injury risk depending on the nature of the impact and point of contact.

The application of line-weighting configurations in pelagic longline fisheries reflects a balance between competing operational and ecological objectives. Heavier weights were introduced to increase sink rates and reduce seabird access to baited hooks. However, to maintain catch performance, particularly where bait movement is important, weights are typically positioned further from the hook to allow the bait to move freely within the water column. This configuration introduces a trade-off in relation to flyback risk, as increasing the distance between the hook and the weight increases the likelihood that the weighted component is out of the water during hauling operations, thereby increasing the potential for high-energy recoil events if line failure occurs.

In this context, safety outcomes are not determined by any single parameter, but by the interaction between weight, velocity, position along the branchline and the frequency of exposure to flyback events. While the 98g SSL configuration demonstrated favourable performance in reducing recoil velocity under controlled conditions, its application in commercial fishing operations must also consider how gear is deployed, handled and interacted with under variable environmental and operational conditions.

Shortened sliding “safety lead” configurations emerged as a promising option that can reduce flyback risk while maintaining acceptable sink rates and operational performance. These systems demonstrated advantages in terms of reduced recoil severity, improved handling characteristics and reduced bin tangling when compared to existing lumo leads and conventional weighted swivels. From an industry adoption perspective, their relative simplicity and cost comparability are also important considerations.

In contrast, some alternative concepts assessed in the project, such as integrated weighted hooks and certain hook shielding devices, presented safety or operational drawbacks that limit their suitability for widespread adoption in the ETBF. These findings directly address Objective 3 by identifying configurations that improve crew safety without compromising mitigation effectiveness.

It is important to recognise that any flyback event represents a work health and safety risk, irrespective of the configuration used.

Observations from both field operations and simulation work confirm that even relatively small components, including hooks and swivels, can cause serious injury when released under tension. As such, reducing recoil velocity alone does not eliminate risk.

In practice, the severity of injury is likely influenced by multiple factors, including the mass and geometry of the impacting object, the location of impact and the frequency with which crew are exposed to flyback events during normal fishing operations. Configurations that reduce recoil velocity may still present a risk where heavier components are involved or where operational practices increase the likelihood of exposure.

Accordingly, flyback risk is best managed by reducing both the likelihood of occurrence and the consequence of impact, rather than relying on any single parameter such as velocity. This reinforces the need for a system-based approach to mitigation that integrates gear design, operational practices and crew safety considerations.

Effective mitigation must be assessed as an integrated system that balances protected species interaction reduction, catch performance and crew safety within the constraints of commercial fishing operations. These findings underscore the importance of avoiding prescriptive approaches that mandate specific gear configurations without considering their broader operational and safety implications.

4.4 Physical protection systems: effective but vessel-specific solutions

(Objectives 3 and 4)

The investigation of physical protection systems, including flyback screens and flyback bars, demonstrated that engineered barriers can effectively deflect or arrest recoiling terminal gear under controlled conditions. Two screen configurations were assessed, representing different approaches to managing recoil energy. Flexible Hortshade material, when deployed with appropriate slack, performed more effectively by absorbing and dissipating energy from recoiling branchlines, thereby reducing impact severity within the protected area. In contrast, more rigid or highly tensioned screen configurations were less effective, tending to deflect gear unpredictably or fail under load.

These results indicate that the capacity to absorb and dissipate energy, rather than simply block or redirect recoiling gear, is a critical factor in the effectiveness of physical protection systems. In this context, Hortshade material demonstrates strong performance as an impact mitigation barrier under controlled conditions and represents an effective option for reducing the consequence of flyback events.

However, the application of such systems in a commercial fishing environment is dependent on vessel-specific factors, including deck layout, installation requirements, interaction with fishing operations, visibility and crew acceptance.

As a result, physical protection systems are best considered as targeted engineering controls that can be applied where operationally feasible, particularly in vessel configurations associated with elevated flyback risk, rather than as universally applicable solutions across the fleet.

These findings align with Objective 4, which explored engineering-based risk controls where gear-based solutions alone may be insufficient, while reinforcing the need for fit-for-purpose application rather than prescriptive implementation.

4.5 Implications for management settings, extension and future mitigation pathways

(Objectives 2, 6 and 7)

The findings of this project highlight that protected species mitigation measures cannot be assessed in isolation. Individually, measures such as line weighting, circle hooks and monofilament leaders are effective in addressing specific interaction risks with seabirds, turtles and sharks. However, when implemented in combination, these measures alter the mechanical behaviour of the branchline system in ways that were not originally considered from a work health and safety perspective.

In particular, the combination of increased line weighting, hook design and leader material influences line tension, failure dynamics and the potential for recoil events. These interaction effects can increase both the likelihood and consequence of flyback events, representing an unintended outcome of otherwise effective mitigation strategies.

This project demonstrates that mitigation effectiveness and crew safety are intrinsically linked and must be considered as part of an integrated system. The results underscore the need for mitigation measures to be evaluated not only for their individual performance, but also for their combined effects under operational fishing conditions.

These findings highlight an important gap in the development and implementation of mitigation frameworks, where the cumulative impact of multiple measures on crew safety has not been fully assessed. Addressing this gap is critical to ensuring that mitigation strategies achieve ecological objectives without introducing unintended risks to those operating within the fishery.

Taken together, the project outcomes have important implications for fisheries management and extension. The results suggest that regulatory frameworks and advisory guidance should avoid prescribing specific mitigation devices without due consideration of WHS performance and operational feasibility. Instead, management settings that allow for adaptive, outcomes-focused approaches are more likely to achieve sustained reductions in protected species interactions while protecting crew safety.

The project also demonstrates the critical role of extension in translating technical findings into practical change.

The development of targeted extension products under this project reflects recognition that adoption depends not only on strong empirical evidence, but on clear communication, demonstration and peer-to-peer learning. This directly addresses Objective 6, which sought to improve data gathering, analysis capability and information sharing within the ETBF.

Finally, while the research was undertaken in Australian conditions, many of the findings are directly relevant to longline fisheries internationally. The integration of safety, effectiveness to reduce protected species interactions and practicality provides a framework that can inform future domestic management reviews, RFMO discussions and the evolution of international best-practice guidance.

5. Conclusion

This project has demonstrated that further improvements in protected species mitigation within the ETBF can be achieved by integrating conservation effectiveness, crew safety and operational practicality, rather than treating these objectives in isolation. By systematically evaluating existing and emerging mitigation tools through both field trials and controlled simulation, the project contributes to a growing body of evidence that safer, and potentially more workable solutions are available to industry that may achieve improved and safer mitigation tools while meeting protected species conservation goals.

Across many components of the study, mitigation performance was often influenced by how equipment behaves under real operating conditions.

Tools that are stable, predictable and easy to deploy were more likely to deliver consistent protected species deterrence and be used correctly by crews. Conversely, mitigation approaches that increase complexity or stored kinetic energy were shown to elevate work health and safety risks and undermine long-term adoption. These findings directly address the project’s objectives to improve effectiveness, efficiency and safety simultaneously.

The evaluation of alternative tori line designs highlighted that mitigation effectiveness was influenced by multiple interacting operational factors including aerial stability, streamer behaviour, environmental conditions, vessel configuration and operator deployment practices, rather than strict adherence to a single prescribed tori line configuration alone.

Project observations suggested that adaptive and simplified tori line systems may provide a practical pathway toward improving deployment consistency, operational usability and management of the seabird interaction zone across variable commercial fishing conditions while also reducing handling complexity and operational burden.

The findings further indicated that simpler and more stable tori line systems may provide comparable seabird deterrence to more complex configurations under some operational conditions, while also improving deployment safety and operational practicality.

Line-weighting assessments highlighted that increasing branchline weighting as a means of improving sink rate with the aim of reducing seabird access may also materially alter the occupational risk profile of longline fishing operations. Controlled flyback simulations demonstrated that recoil dynamics and potential injury outcomes were influenced by multiple interacting factors including total branchline mass, weight placement, type of weight, recoil trajectory and operational configuration, rather than weight magnitude alone.

While heavier line weighting configurations produced substantially lower recoil velocities under controlled conditions, the increased projectile mass associated with these systems retained the potential to transfer substantial momentum and impact energy during flyback events. Consequently, reduced recoil velocity may not necessarily equate to proportionally lower injury severity, and increasing line weighting alone may not represent the optimal pathway from a work health and safety perspective.

Project observations suggested that shortened sliding safety leads may provide a practical risk-reduction approach where correctly configured and maintained, particularly by reducing the likelihood of weighted components recoiling during bite-off scenarios when the sliding mechanism functioned as intended. However, the findings also demonstrated that incorrect ferrule adjustment or operational setup could compromise sliding performance and reintroduce flyback risk.

The results further highlighted that line-weighting performance involves balancing multiple operational considerations including flyback risk, bait presentation, branchline behaviour, shark interactions and fishing practicality. Several alternative configurations introduced operational, safety or fishing performance trade-offs that may limit their broader suitability or uptake within the ETBF under some operating conditions.

Physical protection systems, including flyback screens and flyback bars, were shown to be effective engineering controls for reducing flyback injury risk under specific conditions. However, their applicability is vessel-specific, reinforcing that such measures are best considered as targeted risk controls rather than universal solutions.

Collectively, the project has met its objectives by identifying mitigation approaches that improve crew safety, maintain or enhance seabird deterrence, and support efficient fishing operations. The outcomes reinforce the importance of defining “effective mitigation” in a manner that explicitly includes work health and safety and operational feasibility. By doing so, the project provides a robust evidence base to inform future management settings, industry practice and extension efforts, both within Australia and in comparable longline fisheries internationally.

6. Implications

The outcomes of this project have implications across multiple end-user groups, reflecting the interconnected nature of fisheries management, industry operations, workforce safety and market confidence. By demonstrating that seabird mitigation can be improved through safer, more practical and adaptable approaches, the project provides benefits that extend beyond the ETBF and are relevant to fisheries governance and sustainability outcomes more broadly.

6.1 Industry and fishing businesses

For fishing operators and crews, the project provides evidence that improvements in protected species mitigation do not necessarily require acceptance of increased work health and safety risk. Rather, the findings support a more holistic mitigation approach in which seabird deterrence, operational practicality and crew safety are considered together when developing and refining mitigation systems.

Several mitigation approaches assessed during the project demonstrated promising operational characteristics, most notably shortened sliding safety leads incorporating sliding lumo weights, adaptable dual tori line systems designed to maintain effective protection of the seabird interaction zone under varying operational and environmental conditions, and physical protection concepts including flyback bars and flyback screens. Project observations and controlled simulations suggested that some of these approaches may provide practical pathways toward improving mitigation performance while simultaneously reducing handling complexity, redirecting or dissipating flyback energy, lowering crew exposure to recoil events and reducing overall operational burden.

Collectively, the findings indicate that adaptive mitigation systems and integrated engineering controls capable of being refined to suit prevailing fishing conditions warrant serious consideration as part of future protected species mitigation strategies within commercial longline fisheries.

From an operational perspective, participating fishers generally considered several of the preferred mitigation approaches identified in the project to be broadly comparable in cost and practicality to existing equipment or to involve only modest incremental investment. Shortened sliding safety leads, for example, were commonly viewed by operators as similar in overall cost and handling requirements to commonly used weighted swivel configurations, while also potentially reducing secondary operational issues such as hook bin tangles, gear damage and flyback risk.

Similarly, adaptable tori line components and simplified deployment configurations were viewed favourably by participating operators because they relied largely on readily available materials and fabrication approaches familiar to industry, thereby limiting practical barriers to uptake and vessel integration.

While the project did not undertake a formal economic assessment or comparative cost analysis of mitigation devices, industry feedback consistently indicated that operational practicality, ease of integration, durability, handling characteristics and perceived safety benefits were important considerations influencing the likelihood of long-term adoption within commercial fishing operations.

The benefits to industry include:

- reduced risk of serious injury from flyback events
- improved ease of deployment and handling of mitigation gear
- more consistent mitigation performance across variable conditions
- greater confidence that mitigation requirements are achievable without compromising operational efficiency

Over time, these benefits are likely to translate into fewer incidents, reduced lost fishing time, and improved retention and wellbeing of skilled crew.

6.2 Fisheries managers and regulators

For fisheries managers and regulators, the project provides evidence to support consideration of outcome-focused management settings that prioritise both conservation performance and crew safety. The findings demonstrate that mandating specific mitigation devices without regard to WHS performance can inadvertently increase risk, potentially conflicting with broader government obligations around workplace safety and duty of care.

The results support management approaches that:

- allow flexibility in how mitigation outcomes are achieved
- avoid locking fisheries into unsafe or impractical gear configurations
- recognise the value of adaptive systems that respond to environmental variability

From a cost–benefit perspective, enabling safer and more practical mitigation tools is likely to reduce compliance costs over time by improving uptake and consistency of use. Clearer alignment between mitigation policy and operational reality also reduces the need for reactive regulatory intervention following incidents or industry concern.

The project also provides technical input that can inform future reviews of the Seabird Threat Abatement Plan, AFMA management arrangements and advisory material, ensuring that safety considerations are explicitly incorporated alongside environmental objectives.

6.3 Consumers and markets

For consumers, the outcomes of this project reinforce confidence that Australian tuna fisheries continue to improve their environmental performance while maintaining high standards of social responsibility. Demonstrating that protected species mitigation is delivered through safe, practical and evidence-based measures supports broader expectations around ethical seafood production.

Improved safety outcomes for crews and continued reductions in protected species interactions contribute to the integrity of sustainability credentials, including third-party certification schemes. While consumers do not directly bear the costs of mitigation equipment, reduced injury risk and operational disruption help stabilise supply chains and support the long-term viability of domestic tuna products.

6.4 Certification schemes and international processes

The integration of work health and safety considerations into protected species mitigation assessment has relevance for certification bodies, regional fisheries management organisations and international best-practice guidance processes. The project demonstrates that mitigation effectiveness should not be assessed in isolation from operational risk, and that safer alternatives can deliver equivalent conservation outcomes.

The findings provide practical evidence that can inform:

- future ACAP best-practice guidance
- RFMO discussions on protected species mitigation standards
- international adoption of safety-informed mitigation approaches

By grounding recommendations in empirical testing and real-world operational experience, the project contributes to a more balanced and implementable approach to protected species mitigation globally.

6.5 Research, extension and future investment

The project highlights the value of applied, industry-led research that directly engages end users throughout design, testing and extension. Investment in extension products under this project has ensured that findings are translated into practical guidance rather than remaining solely in technical reports.

From a cost–benefit perspective, targeted investment in extension and demonstration is likely to yield high returns through improved uptake, reduced incident rates and better alignment between policy intent and on-water practice. The outcomes also identify clear pathways for future research to refine adaptive systems, assess vessel-specific engineering controls and further integrate safety and conservation objectives.

7. Recommendations

Based on the findings of this project, the following recommendations are made to support continued improvements in protected species mitigation effectiveness, crew safety and operational efficiency in the ETBF. These recommendations are directed at industry, fisheries managers, regulators and research funders, and reflect the evidence generated through field trials, controlled simulations and industry engagement.

7.1 Adopt safer line-weighting configurations that balance sink rate and WHS performance

It is recommended that industry and managers prioritise the use of line-weighting configurations that demonstrably reduce flyback injury risk while maintaining effective sink rates. In particular, shortened sliding safety lead systems should be supported as a preferred option where they provide comparable seabird deterrence to conventional weighted swivels with reduced recoil severity.

Conversely, mitigation approaches that increase stored kinetic energy and elevate injury risk, such as heavily weighted terminal gear or integrated weighted hooks with high recoil velocities, should not be promoted or mandated without further safety validation. Any future revisions to mitigation guidance should explicitly consider WHS performance alongside conservation outcomes.

7.2 Support adaptive and simplified tori line systems rather than rigid standardisation

The project findings support a move away from highly prescriptive tori line specifications toward outcome-based requirements that prioritise consistent aerial coverage, stability and ease of deployment. It is recommended that management settings allow vessels to deploy adaptive tori line configurations suited to prevailing wind, sea state and vessel layout, provided mitigation outcomes are achieved.

Further refinement and voluntary uptake of simplified and detachable tori line components should be encouraged, particularly where these reduce handling risks, tangling and deployment errors. This approach is likely to improve compliance, reduce operational burden and enhance overall mitigation effectiveness.

7.3 Treat physical flyback protection systems as targeted, vessel-specific controls

Physical protection measures such as flyback screens and flyback bars represent promising engineering control concepts for reducing crew exposure to flyback events within commercial longline operations. The technologies offer potential to either dissipate flyback energy or redirect recoil trajectories away from occupied working areas, thereby reducing the likelihood of direct crew impact during high-energy recoil events.

The project observations and controlled simulations highlighted that the effectiveness of these systems is likely to depend on factors including vessel layout, installation configuration, operational practices and integration with existing deck arrangements. Consequently, physical protection systems are likely to be most effective where they can be adapted and refined to suit individual vessel characteristics and operational requirements rather than applied through a single prescriptive configuration.

The findings support continued refinement and evaluation of physical protection technologies as part of broader efforts to improve work health and safety outcomes within commercial longline fisheries. Future development pathways may include vessel-specific design optimisation, additional engineering assessment and integration with other mitigation approaches aimed at simultaneously improving crew safety and protected species mitigation outcomes.

7.4 Integrate work health and safety considerations into mitigation policy and guidance

The outcomes of this project demonstrate the importance of explicitly integrating WHS considerations into protected species mitigation frameworks. It is recommended that future reviews of mitigation policies, advisory material and best-practice guidance incorporate safety performance as a core assessment criterion, alongside effectiveness and practicality.

This integration will help ensure that mitigation requirements do not inadvertently increase injury risk and that fisheries management settings remain aligned with broader government obligations relating to workplace safety and duty of care.

7.5 Continue targeted extension to support uptake and consistent application

The project highlights that effective extension is essential to translate research outcomes into on-water practice. It is recommended that the extension products developed under this project be actively disseminated and updated as needed, with a focus on practical guidance, visual materials and peer-to-peer learning.

Ongoing investment in extension should be prioritised where it supports safer gear configurations, improves consistency of mitigation deployment and reinforces industry ownership of outcomes.

7.6 Prioritise future research that builds on adaptive and safety-focused mitigation

Future research should focus on:

- refining adaptive tori line systems under a broader range of operating conditions
- further evaluating shortened safety leads across different bait types
- improving vessel-specific engineering controls for flyback risk
- integrating behavioural, oceanographic and safety data to optimise mitigation performance

Such work should continue to adopt an applied, industry-led approach to ensure findings remain practical, transferable and cost-effective.

8. Further development

While this project has delivered practical, industry-ready outcomes, it has also identified several areas where further development would enhance the effectiveness, safety and scalability of protected species mitigation in the ETBF and comparable longline fisheries. These opportunities represent logical extensions of the work undertaken and are intended to guide future research, innovation and investment rather than prescribe management action.

8.1 Refinement of adaptive tori line systems

Further development of adaptive tori line systems would enable more precise optimisation of seabird deterrence across a wider range of operating conditions. Future work could focus on:

- refining streamer materials and configurations to maximise visibility and durability while minimising drag and entanglement risk
- improving attachment and release mechanisms to further reduce the consequences of accidental gear interaction
- assessing paired and offset tori line deployments under all sea-state conditions
- integrating improved storage and retrieval systems, including mechanised or semi-mechanised solutions, to reduce manual handling risk and crew fatigue

Such refinements would support broader adoption of adaptive systems and provide additional confidence to both industry and managers regarding performance and safety.

8.2 Expanded evaluation of line-weighting configurations

While shortened sliding safety leads demonstrated strong potential in this project, further development could examine their performance across a broader range of fishing scenarios.

Future research could include:

- comparative trials under different bait types, including live bait and mixed bait strategies
- assessment of long-term durability and maintenance requirements
- evaluation of performance across different vessel sizes and gear configurations
- integration with companion projects examining sink rate and oceanographic drivers

This work would strengthen the evidence base for safe, effective line-weighting options and support their transferability to other fisheries.

8.3 Vessel-specific engineering controls for flyback risk

The project demonstrated that physical protection systems can be highly effective when tailored to individual vessel layouts. Future development could focus on:

- modular design concepts that reduce custom fabrication costs
- lighter-weight materials that maintain structural performance while improving ease of handling
- improved integration with deck workflows and maintenance routines
- evaluation of long-term durability and crew acceptance under normal fishing operations

Advancing these concepts would assist in developing scalable engineering solutions for vessels with elevated flyback risk profiles.

8.4 Integration of safety, behavioural and environmental data

Future development could also explore the integration of multiple data streams to further optimise mitigation performance. This may include:

- linking seabird behaviour observations with real-time environmental conditions
- combining flyback simulation data with operational incident and near-miss reporting
- refining models that balance sink rate, seabird access risk and crew safety

Such integrated approaches would support more predictive and preventative mitigation strategies rather than reactive responses.

8.5 Continued innovation through industry-led collaboration

Finally, the project has demonstrated the value of close collaboration between industry, researchers and technical specialists. Future development would benefit from maintaining this model, with fishers actively involved in concept design, testing and refinement. This approach ensures that innovation remains grounded in operational reality and that new solutions are more likely to be adopted at scale.

8.6 Adaptive mitigation frameworks and accountability systems

The project findings also highlighted opportunities for future development of more adaptive and outcome-focused approaches to protected species mitigation management within commercial longline fisheries.

Current mitigation frameworks are largely based on compliance with prescribed equipment specifications and standardised deployment requirements. However, the project demonstrated that mitigation effectiveness within commercial fishing operations is influenced by multiple interacting factors including vessel configuration, environmental conditions, fishing practices, deployment stability and operator skill.

Future development could therefore explore management approaches that maintain clear conservation objectives while providing operators with greater flexibility to adapt mitigation systems, deployment practices and fishing behaviour to prevailing operational and environmental conditions. The objective would be to maintain and enhance effective protection of protected species, including seabirds, sharks, turtles and marine mammals, through demonstrated operational performance and adaptive mitigation practices rather than sole reliance on prescriptive equipment specifications.

Such approaches would require appropriate accountability and verification mechanisms capable of independently assessing mitigation deployment, operational performance and protected species interaction outcomes at the individual vessel level. This includes the use of electronic monitoring systems, and operational reporting frameworks with targeted human observer programs in the absence of electronic monitoring.

Within such a framework, responsibility for achieving protected species mitigation outcomes would increasingly shift toward demonstrated operational performance rather than sole reliance on compliance with fixed equipment specifications. Future development of adaptive mitigation frameworks may therefore provide opportunities to simultaneously improve seabird conservation outcomes, operational practicality, innovation and crew safety across commercial longline fisheries.

The project findings suggest that continued collaboration between industry, researchers, managers and technology providers will be important in developing practical systems capable of balancing accountability, operational flexibility and effective protected species mitigation outcomes under real-world fishing conditions.

9. Extension and Adoption

Effective extension and adoption were central to the design and delivery of this project. From the outset, the research was structured to ensure that findings would be translated into practical, industry-ready guidance rather than remaining solely as technical outcomes. Extension activities were therefore integrated throughout the project lifecycle, supporting early uptake, iterative refinement and longer-term behavioural change within the ETBF.

9.1 Extension approach

The extension strategy adopted under this project was deliberately industry-led and practice-focused. Fishing Masters and crew were engaged during concept development, field trials and evaluation, ensuring that extension products reflected real operational conditions and addressed barriers to adoption as they arose.

Extension activities were designed to:

- support consistent messaging of mitigation tools
- improve understanding of the safety implications of different mitigation configurations
- reinforce the rationale for adopting safer and more practical alternatives
- enable peer-to-peer learning and informal knowledge transfer within the fleet

This approach recognised that uptake is strongly influenced by practicality, trust and demonstrated benefit, particularly in relation to work health and safety.

9.2 Extension products developed

A suite of extension products was developed to support adoption of project outcomes, including:

- practical guidance materials outlining preferred mitigation configurations
- visual and diagrammatic resources demonstrating safe deployment and handling
- presentations and workshops delivered to industry forums and meetings
- on-vessel demonstrations and direct engagement with participating crews

Where appropriate, extension materials were aligned with outputs from companion projects (2021-078) to ensure consistency of messaging and reduce duplication. This coordinated approach improved clarity for industry and supported efficient dissemination.

9.3 Adoption by industry

Adoption of project outcomes commenced during the life of the project, particularly where changes delivered immediate and observable benefits to crew safety and operational efficiency. Several mitigation concepts progressed beyond trial evaluation and were voluntarily incorporated into routine fishing operations by participating vessels.

At the completion of the project, three vessels had installed flyback bars and some vessels had adopted flyback deflection screens as engineering controls to reduce crew exposure to recoil events. In addition, modified sliding lumo weight systems had been adopted or trialled by up to ten vessels within the fleet, reflecting industry interest in configurations that may reduce flyback risk while maintaining operational practicality.

Beyond direct adoption of specific technologies, an important project outcome was the increased understanding by operators and crews of the factors contributing to flyback events and other operational risks associated with protected species mitigation measures. This resulted in numerous vessel-specific adjustments being implemented to reduce crew exposure to recoil hazards. For example, some operators modified deck handling procedures and the positioning of the mainline relative to branchline retrieval points so that crew retrieving shark clips from the mainline were encouraged to draw branchlines from the gunwale rather than at chest height, thereby reducing potential exposure to recoil trajectories.

Several factors supported adoption:

- compatibility with existing fishing practices and vessel layouts
- minimal additional equipment requirements relative to existing systems
- observable safety and operational benefits during normal fishing operations
- flexibility to adapt systems to individual vessel requirements
- direct involvement of fishers in concept development, testing and refinement

While adoption during the project provides an early indication of industry interest, it is important to recognise that much of the project's extension and communication program remains ongoing. The adoption figures reported here therefore represent a point-in-time assessment rather than the full extent of potential industry uptake. As project findings, extension materials and practical demonstrations are shared more broadly throughout the ETBF, further adoption of both technological innovations and operational practices developed through the project is anticipated. Given that uptake to date has occurred voluntarily and has largely been driven by observed operational and safety benefits, there is reasonable expectation that implementation will continue beyond the project timeframe.

Importantly, adoption was voluntary and driven by demonstrated operational value rather than regulatory requirements. The willingness of operators to implement both technological and behavioural changes during the project provides evidence that practical, industry-led innovation from this project can support the uptake of mitigation measures beyond the project timeframe.

9.4 Engagement with managers and broader stakeholders

Project findings and extension materials were shared with fisheries managers and advisory bodies to support broader understanding of the relationship between mitigation effectiveness and crew safety. This engagement helped ensure that extension outcomes informed not only industry practice but also future management discussions and policy development.

The project also contributed to broader knowledge exchange through presentations to national and international forums, supporting transferability of findings to other longline fisheries and reinforcing Australia's leadership in safe and effective seabird mitigation.

9.5 Project outcomes achieved through extension and adoption

Extension activities undertaken as part of this project directly contributed to the achievement of several tangible project outcomes. By embedding extension alongside field trials and simulation work, the project ensured that findings were rapidly translated into changes in on-water practice rather than remaining theoretical.

Key outcomes achieved through extension and adoption include:

- increased awareness among fishers of the relationship between mitigation gear configuration, seabird deterrence and flyback injury risk
- early voluntary uptake of safer line-weighting configurations, particularly shortened safety leads, by participating vessels
- improved consistency in tori line deployment and maintenance practices, supported by practical guidance and visual materials
- enhanced industry understanding of why certain mitigation concepts present unacceptable safety or operational trade-offs
- improved confidence among managers and stakeholders that mitigation outcomes can be achieved without increasing WHS risk

Collectively, these outcomes demonstrate that extension played a critical role in ensuring the project delivered real-world impact aligned with its original objectives, particularly those relating to safety, practicality and uptake.

Extension materials can be found on the FRDC Website - **FRDC Project Page 2020-041** or on the Tuna Australia web page for the project - **Improving the effectiveness, efficiency and safety of mitigation tools for protected species interactions in the Eastern Tuna and Billfish fishery**.

9.6 Media, industry and government engagement

The project achieved visibility across industry, research and management audiences through targeted communication and engagement activities (**Table 9.1**). This exposure supported broader awareness of the project's objectives and reinforced the importance of integrating safety considerations into protected species mitigation.

Project findings and demonstrations were featured through:

- presentations and interactive demonstrations at industry and seafood research forums, including Seafood Directions (Appendix 8) and related national events
- industry communications distributed through Tuna Australia member updates and advisory materials
- engagement with fisheries managers and government representatives through briefings, workshops and advisory processes
- inclusion of project outcomes in broader discussions relating to seabird mitigation, work health and safety and best-practice guidance

In addition, elements of the project, particularly the flyback simulation work and practical mitigation demonstrations were used as case studies to illustrate applied, industry-led research to government and research funding bodies. This engagement helped position the project as an example of how safety, conservation and operational efficiency can be addressed concurrently.

Where media coverage occurred, it focused on innovation, crew safety and the practical nature of the solutions being developed, reinforcing positive perceptions of the Australian tuna industry's commitment to responsible and safe fishing practices.

9.7 Ongoing extension and legacy outcomes

The extension products developed under this project provide a foundation for continued uptake and refinement beyond project completion. Tuna Australia will continue to use these materials in routine engagement with members, induction of new crews and discussions with regulators and certification bodies.

By embedding extension within existing industry communication channels, the project ensures that outcomes remain accessible, current and influential over time. This approach maximises return on investment by extending the benefits of the research well beyond the formal life of the project.

Table 9.1 Communication and extension activities undertaken during the project, including target audience and outcomes.

Output type	Title / content	Year	Audience	Format / outlet	Purpose / outcome
Industry news article	*Crew safety at the forefront in new Tuna Australia research project* (Bevitt)	2020	Industry, government, seafood stakeholders	Tuna Australia website	Announced project commencement and positioned crew safety as a core research objective
Industry news article	*New technologies and tools to improve crew safety at sea* (Bevitt)	2022	Industry, regulators, seafood sector	Tuna Australia website	Highlighted emerging tools and interim outcomes; reinforced safety-led innovation
Industry news article	*Using tech to test safety of fishing equipment to protect workers* (Bevitt)	2024	Industry, researchers, policy makers	Tuna Australia website	Showcased flyback simulator testing and applied mitigation research
Industry presentation	Improving the effectiveness, efficiency and safety of mitigation tools for protected species interactions	2020–2025	Tuna longline fishers, Fishing Masters, crew	PowerPoint presentation (pptx)	Communicated project findings and safer mitigation pathways directly to end users
Industry & research forum	Flyback risk and mitigation tools – interactive demonstration	2024	Industry, researchers, managers	Seafood Directions “Fish Tank” session	Demonstrated flyback dynamics and mitigation performance in an applied forum
Industry recognition (award)	Winner – Safety & Research category	2024	Seafood industry, government, public	Queensland Seafood Industry Awards	Recognised excellence in applied safety-focused research
Industry recognition (award)	Winner – Safety category	2024	Seafood industry, government, public	NSW Seafood Industry Awards	Recognised leadership in improving crew safety outcomes
Industry recognition (award)	Honourable Mention – Research	2024	Seafood industry, researchers	NSW Seafood Industry Awards	Acknowledged contribution and impact of FRDC Project 2020-041
Industry recognition (nomination)	Nominee – Research category	2024	Seafood industry, researchers	Seafood Directions Awards	Recognised applied research innovation
Industry recognition (nomination)	Nominee – Safety category	2024	Seafood industry, managers	Seafood Directions Awards	Recognised leadership in crew safety
Governance communication	FRDC 2020-041 project progress and outcomes	2021–2025	Tuna Australia Board	Board papers and briefings	Ensured governance oversight and strategic alignment
Industry communication	FRDC 2020-041 project updates and advisories	2020–2025	Tuna Australia members	Member newsletters and updates	Supported awareness, early uptake and voluntary adoption

Output type	Title / content	Year	Audience	Format / outlet	Purpose / outcome
On-vessel engagement	Demonstration of revised tori lines and safety leads	2021–2024	Participating Fishing Masters and crew	On-vessel demonstrations	Enabled real-time feedback, refinement and early adoption
Stakeholder / policy presentation	Project outcomes relevant to seabird mitigation and crew safety	2022-2023	Government, industry, NGOs, researchers	Seabird TAP Stakeholder Group meeting	Ensured findings informed national seabird mitigation discussions
International industry presentation	Tuna Australia project outcomes: flyback simulator testing and mitigation tools	2024	NZ HMS industry, managers, researchers	Industry HMS Workshop, Tauranga (NZ)	Transferred project outcomes to New Zealand industry and managers
International conference presentation	Presentation of elements of FRDC Project 2020-041 outcomes	2025	Global tuna industry leaders, researchers, policy makers	XII ANFACO World Tuna Conference (TunaVigo), Vigo, Spain	Extended reach of project outcomes to global tuna sector
International policy presentation	Australian perspective on seabird mitigation, flyback risk and crew safety	2024	WCPFC members, governments, NGOs, scientists	WCPFC CMM 2018-03 informal intersessional review meeting	Ensured project outcomes informed international seabird mitigation policy review

Table 3.3 in Section 3.10 defines the extension products developed to support the release and adoption of outcomes from FRDC Project 2020-041, identifying the product type, content focus and intended target audiences, and provides a foundation for ongoing dissemination that will extend the impact of the project well beyond its formal completion.

10. References

Abery, N.W., Robertson, G., Hall, S., Candy, S., Inwood, A., (2015). Improved line weighting method for tuna longline fishing using livebaiting to mitigate sea bird bycatch and improve worker safety.

ACAP (2004). Agreement on the Conservation of Albatrosses and Petrels, Agreement text, Hobart, Australia.

ACAP (2019). *Best practice advice for mitigating seabird bycatch in longline fisheries*, Agreement on the Conservation of Albatrosses and Petrels, Hobart, Australia. (Note: consolidated advice first issued in 2009, with updates in 2011, 2016, 2019 and 2021.)

ACAP (2021). *Best Practice Seabird Bycatch Mitigation Criteria and Guidelines*, Agreement on the Conservation of Albatrosses and Petrels, Hobart, Australia, viewed [date], https://www.acap.aq.

ACAP (2024). *Review of mitigation measures and Best Practice Advice for Reducing the Impact of Pelagic Longline Fisheries on Seabirds*. Reviewed at the Fourteenth Meeting of the Advisory Committee, Lima, Peru, 12–16 August 2024.

AFMA (2011). *Eastern Tuna and Billfish Fishery environmental assessment report*, Australian Fisheries Management Authority, Canberra.

AFMA (2021). *Eastern Tuna and Billfish Fishery permit conditions for seabird mitigation*, Australian Fisheries Management Authority, Canberra.

AFMA (2025). *Eastern Tuna and Billfish Fishery management arrangements booklet 2025*, Australian Fisheries Management Authority, Canberra.

Anderson, O. R. J., Small, C. J., Croxall, J. P., Dunn, E. K., Sullivan, B. J., Yates, O. & Black, A. (2011). Global seabird bycatch in longline fisheries. *Endangered Species Research*, 14, 91–106.

Baker, G.B., Candy, S.G. and Rollinson D. (2016). Efficacy of the 'Smart Tuna Hook' in reducing bycatch of seabirds in the South African Pelagic Longline Fishery. Abstract only. Agreement on the Conservation of Albatrosses and Petrels, Seventh Meeting of the Seabird Bycatch Working Group, 2 - 4 May 2016, La Serena, Chile, SBWG7 Inf 07.

Brothers, N, Cooper, J & Løkkeborg, S. (2010). *The incidental catch of seabirds by longline fisheries: worldwide review and technical guidelines for mitigation*, FAO Fisheries and Aquaculture Circular No. 937, Food and Agriculture Organization of the United Nations, Rome.

Brothers, N (2024). Personal communication to Project Manager regarding tori line design principles, Humane Society International, Hobart.

Cambiè, G., Muiño, R., Freire, J., & Mingozzi, T. (2012). *Effects of small (13/0) circle hooks on loggerhead sea turtle bycatch in a small-scale pelagic longline fishery*. Bulletin of Marine Science, 88, 719–730.

CCSBT (2011). *Information on seabird mitigation measures in the Eastern Tuna and Billfish Fishery*, CCSBT Information Paper Info03, Commission for the Conservation of Southern Bluefin Tuna.

Commonwealth of Australia (2001). *Threat Abatement Plan for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations*, Environment Australia, Canberra.

Commonwealth of Australia. 2018. *Threat Abatement Plan for the Incidental Catch (or Bycatch) of Seabirds During Oceanic Longline Fishing Operations (2018)*. Department of the Environment and Energy, Canberra.

D'Alberto, B., Patterson, H. and Bromhead, D, (2024). The influence of wire leaders and shark lines on shark bycatch in pelagic longline fisheries: A review and implications for the IOTC, ABARES technical report 24.04, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, March, DOI: 10.25814/vn7g-h886. CC BY 4.0

DAWE (2018). *Threat Abatement Plan for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations*, Department of Agriculture, Water and the Environment, Canberra.

Environment Australia (1998). *Threat Abatement Plan for the incidental catch (or bycatch) of seabirds during oceanic longline fishing operations*, Environment Australia, Canberra.

FAO (1999). *International Plan of Action for reducing incidental catch of seabirds in longline fisheries*, Food and Agriculture Organization of the United Nations, Rome.

Gilman, E., Zollett, E., Beverly, S., Nakano, H., Davis, K., Shiode, D., Dalzell, P., & Kinan, I. (2006). *Reducing sea turtle by-catch in pelagic longline fisheries*. Fish and Fisheries, 7, 2–23.

Gilman, E., Kobayashi, D., Swenarton, T., Brothers, N., Dalzell, P., & Kinan-Kelly, I. (2007). *Reducing sea turtle interactions in the Hawaii-based longline swordfish fishery*. Biological Conservation, 139, 19–28.

Goad, D., Debski, I. & Potts, J. 2019. *Hookpod-mini: a smaller potential solution to mitigate seabird bycatch in pelagic longline fisheries*. Endangered Species Research 39: 1–8. https://doi.org/10.3354/esr00953.

ICCAT (International Commission for the Conservation of Atlantic Tunas). 2007. Recommendation by ICCAT on reducing incidental bycatch of seabirds in longline fisheries [Rec. 2007-07]. International Commission for the Conservation of Atlantic Tunas, Madrid, Spain.

IATTC (Inter-American Tropical Tuna Commission). 2011. Resolution to mitigate the impact on seabirds of fishing for species covered by the IATTC [Resolution C-11-02]. Inter-American Tropical Tuna Commission, La Jolla, California, USA.

IOTC (2019) *Resolution on mitigation of seabird bycatch*, Indian Ocean Tuna Commission.

Jiménez, S., & Barrington, J.H. (2021). *Best Practice Seabird Mitigation Tools and Techniques: A Review of Efficacy and Applicability in Longline Fisheries*.

Kazuhiro, Y.(2025). Yamazake double weighted branchline [WWW Document].

Lawrence, E, Wise, B, Bromhead, D, Barry, S & Findlay, J.(2005). *Analysis of AFMA seabird mitigation trials 2001–2004*, Bureau of Rural Sciences, Canberra.

Løkkeborg, S. (2011). 'Best practices to mitigate seabird bycatch in longline, trawl and gillnet fisheries', *FAO Fisheries and Aquaculture Technical Paper*, no. 556, Food and Agriculture Organization of the United Nations, Rome.

McCormack, A. & Papworth, W. (2014). *Flyback injuries in pelagic longline fisheries: An international survey.* Unpublished report cited in ACAP (2019).

McCormack, T. & Rawlinson, N. (2016). *Fly-back injuries in longline fishing operations: implications of line weighting and recoil velocity*. Commissioned by the Agreement on the Conservation of Albatrosses and Petrels (ACAP)

Patterson, H., Hansen, S. and Larcombe, J. (2014). A review of shark bycatch mitigation in tuna longline fisheries, Canberra, July. CC BY 3.0

Pierre, J. P., Goad, D. W. & Abraham, E. R. (2015). Novel approaches to line-weighting in New Zealand's inshore surface-longline fishery. Final Report prepared for the Department of Conservation, Conservation Services Programme project MIT2012-04.

Gilman, E., Kobayashi, D., Swenarton, T., Brothers, N., Dalzell, P., & Kinan-Kelly, I. (2007). *Reducing sea turtle interactions in the Hawaii-based longline swordfish fishery*. Biological Conservation, 139, 19–28.

, G., Candy, S. G., Wienecke, B. & Lawton, K. (2010). Experimental determinations of factors affecting the sink rates of baited hooks to minimise seabird mortality in pelagic longline fisheries. *WCPFC-SC6-2010/EB-WP-06.*

Silva-Costa, A., Neves, T., Marques, C., Gianuca, D., Winnard, S. & Yates, O. 2017. *The performance of Hookpods under commercial fishing conditions in the Brazilian pelagic longline fleet*. SBWG8 Inf 08. Eighth Meeting of the Seabird Bycatch Working Group, Agreement on the Conservation of Albatrosses and Petrels (ACAP), Wellington, New Zealand.

Sullivan, B. J. et al. (2017). At-sea trialling of the Hookpod: a one-stop mitigation solution for seabird bycatch in pelagic longline fisheries. *Animal Conservation*, 21, 159–167.Tuna Australia (2021). *Industry survey of tori line use and performance in the Eastern Tuna and Billfish Fishery*, internal report, Tuna Australia, Canberra.

Sullivan, B. (2025). Hookpod - Product Details [WWW Document]. URL https://www.hookpod.com/en/product/details/ (accessed 7.8.25).

Ward, P., Lawrence, E., Darbyshire, R., & Hindmarsh, S. (2008). *Large-scale experiment shows that nylon leaders reduce shark bycatch and benefit pelagic longline fishers*. Fisheries Research, 90, 100–108.

Watson, J.W., Epperly, S.P., Shah, A.K., & Foster, D.G. (2005). *Fishing methods to reduce sea turtle mortality associated with pelagic longlines*. Canadian Journal of Fisheries and Aquatic Sciences.

WCPFC (2018). Conservation and Management Measure for seabirds, Western and Central Pacific Fisheries Commission, CMM 2018-03.

Zhou, C. & Brothers, N. (2021). Interaction frequency of seabirds with longline fisheries: risk factors and implications for management. *ICES Journal of Marine Science* doi.org/10.1093/icesjms/fsab014.

11. Project materials developed

A comprehensive suite of physical materials, engineered components, simulation assets and communication products was developed, procured or constructed during the project to support sub-project activities, field trials, controlled simulations and extension to industry and stakeholders. Collectively, these materials underpinned the practical testing of mitigation tools, enabled rigorous assessment of safety and performance, and supported effective communication of project outcomes.

11.1 Field trial and operational materials

To support at-sea trials of seabird mitigation tools under commercial fishing conditions, the following materials were constructed and distributed to participating vessels:

- Sixteen (16) tori lines were built and distributed for the 3.5 m and 5 m tori line trials.
- Ten (10) tori lines were built and distributed for the 7 m tori line trials.
- Fifteen thousand one hundred and eighty (15,180) shortened sliding safety leads were produced and distributed to trial participants. Custom moulds were developed as part of the project to enable ongoing production and continued adoption beyond the life of the project.

These materials enabled consistent, repeatable testing across vessels and supported early uptake of safer configurations by industry.

11.2 Engineered mitigation and safety prototypes

A range of engineered designs and prototype safety devices were developed and evaluated to address identified work health and safety risks associated with longline fishing operations:

- Two (2) prototype flyback safety bars were fabricated, installed and tested on participating vessels.
- Four (4) flyback safety screens were manufactured or procured for comparative testing both onboard vessels and within controlled simulation environments.
- Adjustable tori line design concepts were developed to improve aerial coverage, stability and operational practicality.
- Engineering concepts for flyback control devices, including physical barriers and screening approaches, were assessed through a combination of field deployment and simulation-based testing.

These engineered outputs were central to achieving the project objective of improving seabird mitigation effectiveness without increasing crew injury risk.

11.3 Flyback simulation and testing assets

A dedicated flyback simulation design was developed and progressively refined as a core project output to enable controlled testing of flyback dynamics, recoil velocity and injury risk associated with different branchline and mitigation configurations.

The simulator was designed to replicate key operational parameters observed in commercial longline fishing, allowing repeatable and safe testing that would not be feasible solely through at-sea trials.

The simulator was iteratively refined throughout the project based on observations, engineering inputs and trial results to improve realism, repeatability and relevance to operational conditions. This refinement enabled comparative assessment of line weighting arrangements, shortened safety leads, flyback control devices and physical barriers.

To support simulation trials:

- One hundred (100) branchlines were constructed in multiple configurations.
- Five (5) Yamazaki leaders were integrated into branchlines for dedicated flyback testing.

The simulator was also adapted as an extension and communication tool, supporting visual demonstration of flyback behaviour and mitigation performance during industry workshops, stakeholder briefings and research forums. A three-dimensional (3D) printed physical model of the simulation environment was produced and used to assist explanation of flyback dynamics to industry and stakeholders.

11.4 Communication, extension and training materials

To support extension and adoption of project outcomes, a suite of communication and training materials was developed, including:

- PowerPoint presentations and supporting visual materials used in industry workshops, stakeholder briefings, national and international forums and conferences.
- A comprehensive extension and adoption package comprising infographics, video interviews and fact sheets translating technical findings into accessible, practical guidance for end users.
- Integration of extension outputs with the companion project FRDC 2021–078 to ensure consistency, avoid duplication and reinforce shared safety and mitigation messages.

Together, these materials, including engineered mitigation devices, field trial equipment and the developed and refined flyback simulation model. This supported robust testing, enabled engineering-based safety assessment, and strengthened industry engagement and communication, ensuring that project outcomes were practical, defensible and readily transferable to end users.

Additional images to support project materials can be found in Appendix 13.

12. Appendices

Appendix 1 - Industry survey summary and project direction option

Industry survey summary and WHS mitigation project direction
Phil Ravanello

An industry “road trip” was conducted from 12 March to 28 March 2021 covering the ports of Coffs Harbour, Nelson Bay and Ulladulla. The purpose of the trip was to survey gear, crew, bycatch mitigation and boat configurations to better understand the landscape of current ETBF operators practices, experiences, and attitudes to WHS and bycatch mitigation. Collecting baseline information from these surveys serves as a preemptive assemblage of information to inform and focus future project direction and industry workshops.
The trip was somewhat hampered by the massive rain events and flooding through the north and south coasts of NSW. However, 11 boats were surveyed via wharf interviews over the period and an additional phone interview was conducted with the previous owner of a side setting vessel. When coupled with an additional 11 boats surveyed in Mooloolaba, 23 boats out of the ETBF fleet of 32 active boats is a good representative sample for this project.
The following is a breakdown of the key information coming out of the industry survey which can inform the deliberations and investment decisions of the Steering committee.

Tori Line standardisation
The adverse impacts of longline fishing on seabirds came to prominence during the era when Japanese longlines worked in Australian waters. By the 1990’s, seabird mortalities were estimated to be in the order of 8,000 seabirds (mostly Albatross) each year. As a result, longline fishing was nominated for listing as a key threatening process in 1995 and the Seabird TAP came into effect in 1998. Tori lines have been used in Australian longline fisheries since at least 1996, coinciding with the departure of the Japanese and the establishment of the Eastern Tuna and Billfish Fishery.
The evolution of tori lines has been one of continuous improvement, both in response to the requirements of the TAP and extensive research and testing in global longline fisheries. Initial tori line regulation was based on the aerial extent achievable by larger Japanese vessels (100m). This aerial extent is not replicable on Australian vessels given their smaller size. As such, tori lines need modification to suit Australian conditions. In the Oceania region, this research has been led by the Agreement for the Conservation of Seabirds and Petrels (ACAP), Birdlife International, Southern Seabird Solutions Trust, the Australian Antarctic Division, and other stakeholders.
While the Seabird TAP has documented vast improvements in the number of seabirds killed by longline fishing each year, there is a need to refine current practices further to reduce interactions and ensure consistency of tori line construction and maintenance. Having a consistent, high standard of seabird protection across all boats is key to reducing regulatory and operational burdens on industry.
Project effort should be focused on temporal and spatial seabird interaction data. Review of interaction rates shows that the latitude bans of 25° - 30°,30° - 35°, 35° - 40° and are still most problematic. Operators working consistently North of 25° have less seabird interactions reducing the overall seabird interaction risk profile.

Table 1: Seabird interactions by latitude band for summer and winter TAP seasons 2015 - 2019

A)

		Winter					Summer					
	TAP Zone	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019	Total
Number of Seabirds	40S-45S	0	0	3	0	0	0	13	10	0	0	**26**
	35S-40S	3	5	1	1	20	3	13	29	24	9	**108**
	30S-35S	5	4	0	2	3	4	6	31	46	3	**104**
	25S-30S	2	1	0	2	1	5	1	3	15	34	**64**
	20S-25S	0	0	0	0	0	0	0	1	1	0	**2**
	15S-20S	0	0	0	0	0	0	0	0	0	0	**0**
	10S-15S	0	0	0	0	0	0	0	0	0	0	**0**
Total		**10**	**10**	**4**	**5**	**24**	**12**	**33**	**74**	**86**	**46**	**304**

The industry visit revealed there are several layers of consistent and responsible seabird mitigation. This includes:

- tori line construction
- maintenance
- replacement perspective
- awareness of the requirements and the attitudes of various skippers and companies.

Overall, there is a strong level of support for this component of the project. Many skippers (65% - 15/23 boats as per Table 1) were willing to trial tori lines and provide feedback and improvement advice. Remaining skippers were happy enough with their current tori line designs. The vast majority (85% - 20/23 boats as per Table 1) were supportive of an "off the shelf" solution if available, especially if the design was cost effective and endorsed by AFMA as an industry "standard". Alternatively, a "kit" consisting of the approved materials with detailed instructions, was similarly met with the same level of support. The following table summarises the data collected from the interviews:

Table 2: Tori line construction material summary and attitudes to trial participation and commercialised "standard" tori line

Boat	Tori Line material			Drogue material		Dropper material		Trial	Commercial solution
	Mono	Rope	Other	Mono	Other	Kraton	Tape		
1	✗	✓	✗	✗	✓	✗	✓	✓	✓
2	✗	✗	✓	✗	✓	✗	✓	✓	✓
3	✗	✗	✓	✓	✗	✓	✗	✗	✗
4	✗	✗	✓	✗	✓	✗	✓	✓	✓
5	✗	✗	✓	✗	✓	✗	✓	✓	✓
6	✗	✓	✗	✗	✓	✗	✓	✓	✓
7	✓	✗	✗	✓	✗	✗	✓	✓	✓
8	✗	✓	✗	✗	✓	✗	✓	✗	✗
9	✓	✗	✗	✓	✗	✗	✓	✓	✓
10	✓	✗	✗	✓	✗	✓	✗	✓	✓

11	✓	✗	✗	✓	✗	✓	✗	✓	✓
12	✓	✗	✗	✓	✗	✗	✓	✓	✓
13	✓	✗	✗	✓	✗	✓	✗	✓	✓
14	✓	✗	✗	✓	✗	✓	✗	✓	✓
15	✓	✗	✗	✓	✗	✗	✓	✓	✓
16	✓	✗	✗	✓	✗	✓	✗	✓	✓
17	✗	✓	✗	✗	✓	✗	✓	✓	✓
18	✓	✗	✗	✓	✗	✗	✓	✗	✓
19	✓	✗	✗	✓	✗	✗	✓	✗	✓
20	✓	✗	✗	✓	✗	✗	✓	✗	✓
21	✓	✗	✗	✓	✗	✗	✓	✗	✓
22	✓	✗	✗	✓	✗	✗	✓	✗	✓
23	✗	✓	✗	✗	✓	✓	✗	✗	✗

Key information from this summary table is as follows:

Backbone: 6mm rope is used by 20% (5/23 boats as per Table 1) of the fleet in their tori line construction. 6mm rope is used because it is tough, cheap and easy to splice streamers through, creating less points in the line to create tangles (e.g. by removing cable ties, shark clips etc.). However, the heavier weight of the 6mm rope may be impacting aerial extent. Several boats working in southern latitude bands use 6mm rope.
Other backbones made from 2mm Dyneema, 4mm Venetian cord and Japanese tarred rope (Kuralon) are reportedly achieving acceptable levels of aerial extent, regardless of dropper material chosen. Skippers using these alternate backbone materials have reported a good level of seabird mitigation (i.e. have not breached the TAP). 60% of the fleet (14/23 boats as per Table 2) is using mainline as their backbone which is significantly lighter than 6mm rope and more cost effective than Dyneema.

Streamers: There are two main types of streamers in use, packing tape and Kraton tubing. The Kraton tubing appears to be legacy of a supply given to the Ulladulla fleet by AFMA many years ago and is still performing (longevity). However, there is a disconnect between information provided about how many tori lines are used each year and the original supply of Kraton tubing.

1. the availability of Kraton as dropper material
2. 30% of the fleet (7/23 boats as per Table 2) is still using Kraton streamers.
3. Kraton was generally fixed by cable ties or smallest available shark clips, both of which are potential hook up points in the design.

Packing tape was commonly used on the tori lines observed (70% of fleet – 16/23 boats as per Table 2) and was generally affixed with splices. Feedback on the use of packing tape was overall positive, although storage and tangling are recurring issues. The use of large diameter drums or wheel housings would possibly address this issue. One operator had an interesting innovation whereby he attached fluorescent red Sekiyama thin rope sections as alternate streamers and reported this gave a great contrast against his other packing tape dropper colours of yellow and blue.

Drogue: Operators running 6mm rope as their backbone generally used 100 – 200m of 6mm rope as their drogue. This was constructed as a straight through line with no connectors to provide a hook up point.

The use of mainline as a drogue was common where the backbone was also constructed of mainline, providing a seamless transition with no hook up point. An operator using Japanese tarred rope as a backbone also used 200m of this material as the drogue. The operator using 4mm Venetian cord as a backbone also used 6mm rope for the drogue, the connection being made via a taped up swivel. He reported this as a common entanglement point.

Other drogue variations encountered during the survey included

1. leaded mainline / footrope (used in the demersal longline sector and Antarctic fisheries)
2. length of chain to "anchor" the tori line, and
3. the use of a PVC "dome" over the tori to drogue connection to shield the connection point from hooks or bubbles.

Other design considerations

Experience has shown value by incorporating a breakaway point in the design to ensure 'hookups' do not damage the tori line pole. For example, NZ designs use a tensioned release clip consisting of springs and wing nuts along a threaded bolt to add appropriate tension, with a release clip captured between the springs and attached to the mainline.

To provide further "shape" to the tori line a weighted assembly (e.g. lumo lead chain) could be considered in the design.

This would be consistent with how one operator uses chain to increase drag. This is a concept that has been previously successfully trialed but was never progressed with industry.

Performance issues

All survey participants were asked about the main cause of hook ups of the tori line and how often these events occurred. The answers varied widely, but key consistencies were identified from the survey which may require further consideration.

1. Bubbles and to a lesser degree RF or GPS beacons were responsible for many of the reported hookups. These devices provide a "high point" in the gear which take them closer to the tori streamers. Many fishers reportedly fixed this problem by simply pulling sharply on the tori line, causing the Kraton or packing tape streamer to break off. This has obvious implications for maintenance, tori line performance (if not fixed), and marine pollution.
2. Sudden wind shifts or gusts of wind were reported by most operators as being a factor in tori line hook ups. Fishers generally try to work side on to the wind when shooting where possible to allow the streamers to cover the setting area. In instances where a sharp wind shift occurs, the tori can immediately go slack, or the streamers blown back onto the main line, causing tangles.
3. The number of reported hook ups with tori lines differed markedly between fishers. Some reported tangles as frequently as once every trip, where others had gone a whole season without an issue. There were linkages identified in the survey between tori line materials and design, number of hook ups and reported bird interactions. A new and improved tori line may reduce the incidences of these issues.

4. Safety when deploying tori lines was not identified as a major concern. Most boats had a good system in place for the deployment and retrieval of tori lines. The only concerns raised were the possibility of mainlines or snoods becoming entangled in the propellor when dealing with tori line hook ups.

Project direction

There is good support for the trial / assessment of a premade tori line which can be modified to suit a range of boat sizes, aerial extent coverage and tori pole location relative to the stern of the boat. A prototype design has been submitted for initial costing to inform potential project expenditure. The design is based on the following specs:

Mainline: 3.2mm monofilament mainline 100m. The first 10m does not have streamers so can be adjusted for length relative to stern. Clear mono is the most cost effective option. Coloured mono can only be manufactured to be translucent, so provides negligible benefit, and other backbone materials are cost prohibitive or have performance issues.

Streamers: Quad packing tape streamers and dual packing tape streamers alternatively attached in 3m increments from 10m – 100m.

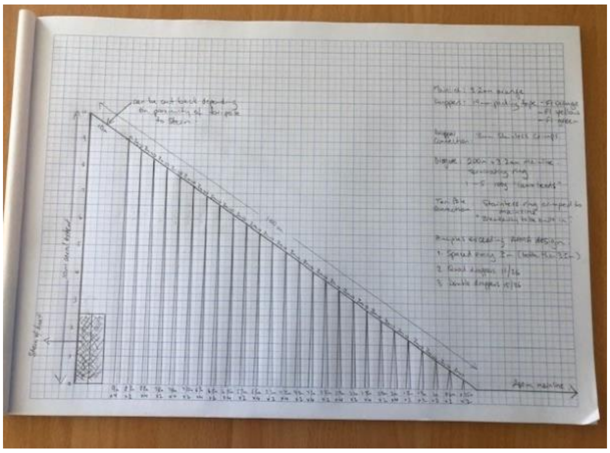
Drogue: 220m of 3.2mm mainline with attachment points for “lumo leads” at the end point of drogue for additional anchoring. Other anchor options include leaded downline, chain or sinkers. The ability to modify the weight (add more or less depending on sea conditions) is a key consideration.

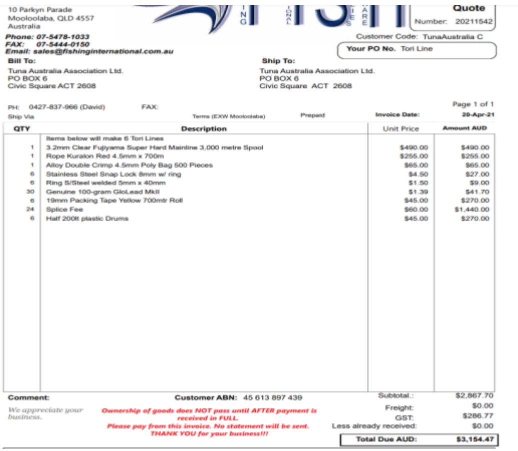
Attachment point: Stainless steel snap and O ring attachment with “breakaway” point. 4.4mm SS crimps to attach streamers to mainline

The tori line costing is based on a 10m aerial extent as this was a commonly quoted tori line pole height. However, the design may need to consider a range of sizes as it appears some smaller vessels would have lower attachment points i.e. 7-8m.

An initial quote has been obtained based on the below design which includes materials and labour to produce up to 8 tori lines.

These will be somewhat experimental in nature and will include two bespoke ones (14 meter aerial extent) for the Instagator to assist current seabird issues. The labour component will come down in price once a technique and process is developed for producing them in bulk.





10 Parkyn Parade
Mooloolaba, QLD 4557
Australia
Phone: 07-5478-1033
FAX: 07-5444-0150
Email: sales@fishinginternational.com.au

Quote
Number: 20211542
Customer Code: TunaAustralia C
Your PO No. Tori Line

Bill To:
Tuna Australia Association Ltd.
PO BOX 6
Civic Square ACT 2608

Ship To:
Tuna Australia Association Ltd.
PO BOX 6
Civic Square ACT 2608

PH: 0427-837-966 (David) FAX:
Ship Via Terms (EXW Mooloolaba) Prepaid
Page 1 of 1
Invoice Date: 20-Apr-21

QTY	Description	Unit Price	Amount AUD
	Items below will make 6 Tori Lines		
1	3.2mm Clear Fujiyama Super Hard Mainline 3,000 metre Spool	$490.00	$490.00
1	Rope Kuralon Red 4.5mm x 700m	$255.00	$255.00
1	Alloy Double Crimp 4.5mm Poly Bag 500 Pieces	$65.00	$65.00
6	Stainless Steel Snap Lock 8mm w/ ring	$4.50	$27.00
6	Ring S/Steel welded 5mm x 40mm	$1.50	$9.00
30	Genuine 100-gram GloLead MkII	$1.39	$41.70
6	19mm Packing Tape Yellow 700mtr Roll	$45.00	$270.00
24	Splice Fee	$60.00	$1,440.00
6	Half 200lt plastic Drums	$45.00	$270.00

Comment: Customer ABN: 45 613 897 439
We appreciate your business.
Ownership of goods does NOT pass until AFTER payment is received in FULL.
Please pay from this invoice. No statement will be sent.
THANK YOU for your business!!!

Subtotal.: $2,867.70
Freight: $0.00
GST: $286.77
Less already received: $0.00
Total Due AUD: $3,154.47

Figure1: Sample 10m tori line and proposed quote to construct initial tori lines

The project steering committee should discuss

1. Tori line design – is there a need for multiple designs to trial?
2. How many should be produced i.e. 3 designs x 3 replicates

What will be the measurement/analysis metrics?

Flyback safety systems

The introduction of the Seabird TAP has mandated several seabird mitigations that AFMA must enforce through permit conditions and compliance. These include the use of tori lines and a line weighting regime. Under AFMA's individual accountability approach, any breach of the TAP by a vessel triggers additional mitigation options that must be applied to the boat or gear, including further additional weighting.

The current line weighting requirements of 40 grams at the hook, 60 grams within 3.5m of the hook, or 90 grams within 4m of the hook have created a serious risk to fisher safety through "flyback or recoil" events. Flybacks occur when a fish, or more commonly sharks, are being "leadered" during landing and the hook is bitten off or torn out of the fishes mouth. Because the line is under great tension, the weighted swivel becomes a dangerous projectile recoiling at great velocity back to the boat. This event places crew in significant danger. Injuries and near misses occur with disturbing regularity. Deaths have known to occur in some foreign fisheries.

While there is a recognition that "flybacks" are a significant safety issue, there are many views about the causes and solutions to the problem. In discussing flybacks during the industry survey, operators were quite circumspect in their views about flybacks, acknowledging that there is a significant issue requiring an immediate solution. Some operators considered that there was scope to reduce the incidence of flybacks with

1. crew training,
2. having experienced skipper or crew working the winch, and
3. a boat level policy for mandatory "dropping of hooks" for sharks.

There have been several recent incidents and many near misses which have sharpened industry focus on solutions, both complex and simple in design. The following is a summary of the discussions with industry about the causes, potential solutions and willingness to trial specific mitigations:

Table 3: "Cause of flyback" results, current mitigation strategy summary and willingness to trial proposed new mitigations.

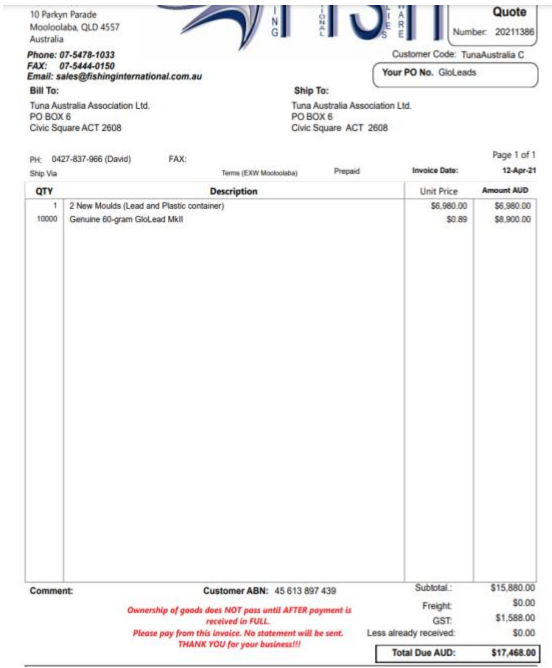
Boat	Cause (sharks, big fish)	Cause (other)	Safety inductions	Boat policy (dropped hook)	PPE	Proposed mitigations				
						LL Bar	WH	SS	Screen	
1	✓	✗	✓	✓	✗	✗	✗	✗	✗	✗
2	✓	✗	✓	✓	✗	✗	✗	✗	✗	✗
3	✓	✓	✓	✓	✗	✗	✗	✗	✓	✗
4	✓	✓	✓	✓	✓	✗	~	✗	✓	✗
5	✓	✓	✓	✓	✓	✗	~	✗	✓	✗
6	✓	✓	✗	✗	✗	✓	✗	✗	✓	✓
7	✓	✗	✓	✗	✗	✓	✗	✗	✓	✓

8	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗
9	✓	✗	✓	✗	✗	✗	✗	✗	✓	✗
10	✓	✓	✓	✗	✓	✓	✗	✗	✗	✓
11	✓	✓	✓	✗	✓	✓	✗	✗	✗	✓
12	✓	✓	✓	✗	✓	✓	✗	✗	✗	✓
13	✓	✓	✓	✗	✓	✓	✗	✗	✗	✓
14	✓	✓	✓	✗	✓	✓	✗	✗	✗	✓
15	✓	✓	✓	✗	✗	✓	✗	✗	✗	✗
16	✓	✓	✓	✓	✗	✗	✓	✗	✗	✗
17	✓	✓	✓	✓	✗	✗	✓	✗	✗	✗
18	✓	✓	✓	✗	✗	✗	✗	✓	✓	✗
19	✓	✓	✓	✗	✗	✗	✗	✓	✓	✗
20	✓	✓	✓	✗	✗	✗	✗	✓	✓	✗
21	✓	✓	✓	✗	✗	✗	✗	✓	✓	✗
22	✓	✓	✓	✗	✗	✗	✗	✓	✓	✗
23	✓	✓	✓	✗	✗	✗	✗	✗	✓	✗

There was complete industry agreement that sharks and to a lesser extent big fish were the cause of flyback incidents. When asked about the number of bite offs that caused flybacks versus tear outs, most operators could not readily apply a percentage between the two causes of flybacks. However, answers such as “mostly, majority, quite often…” for tear outs would indicate that bite offs cause most incidents. This aligns with previous (limited) research done on the issue by Ben Sullivan that determined 80% of flyback incidents occurred due to bite offs and 20% due to tear outs.
Of the non physical mitigations available, all but one skipper stated they actively discussed the risk of flybacks as part of broader crew inductions. The one skipper who said he had not incorporated flybacks into induction training said he would in response to the discussion. Interestingly, 30% of boats stated they had a policy of dropping leaders that were attached to large sharks as these were considered high risk for flyback events and are unable to be landed in any case.

Shortened lumo leads (LL’s)
LL’s have been around for many years and only one fishing company has 100% deployment of them on their longline gear. In the seven years they have been using LL’s they have not had one flyback incident or near miss.
The rate of replacement from gear loss has been consistent with what they would have expected with weighted swivels at a similar price point. Uptake of LL’s in the Australian fishery has been poor for various reasons (mostly related to fish catchability), but they are popularly used in NZ and South African longline fisheries. This solution solves the flyback issue simply by the LL sliding off the snood in the instance of a bite off. This is because under tension, the diameter of the snood decreases allowing the lumo lead to slide down to the hook.
Another fishing company has commenced trialing the standard LL’s, currently using them on 25% of snoods (~3,100 hooks). Feedback has been that the elongated design causes regular bin tangles, and the fluorescent nature of the casing attracting sharks.

Both companies have tried shortening some of the LL's to good effect to eliminate this issue. Unfortunately, the design improvement results in poor longevity due to water ingress in the uncased design.
The survey identified that there are up to 8 boats (35% of fleet – 8/23 boats as per Table 3) that would be willing to replace their weighted swivels and use a revised LL design subject to successful trials.
Fishers were concerned that the wording of the condition regarding "weighted swivels" may technically cause a compliance breach for them by using these solutions to replace swivels. Feedback was provided to AFMA regarding this and the wording of "swivels" have been changed to "weights" in permit conditions to facilitate use of LL's.
To produce a "commercial" shortened LL, new molds will need to be developed and a trial set of LL's produced. The main supplier (Fish International) was a collaborator on the design (in in conjunction with AFMA, Graeme Robertson and others) and is happy to facilitate the production of the molds and trial units at a subsidised rate. The project has a commitment from industry to trial a 100% deployment on their longline gear, encompassing up to 12,400 hooks plus enough spares. The current preference is to provide the casings in one color (deep blue) as the fluoro green colour is considered a fish deterrent when located at the hook, however production in other colours (fluoro green, black etc.) is also possible if there is sufficient demand.
The current quote provides for the development on new molds for the housing and shorted leads and an initial 10,000 LL's produced. This will need to be increased (to 15,000 units?) if the steering committee agrees to six boats being used for the project. Note that the per unit price includes a $0.43 subsidy that has been negotiated with Fish International as a contribution to the project (60g LL currently retail for $1.32 per unit) which represents a $6450 saving over 15,000 LL's.



10 Parkyn Parade
Mooloolaba, QLD 4557
Australia
Phone: 07-5478-1033
FAX: 07-5444-0150
Email: sales@fishinginternational.com.au

Quote
Number: 20211386
Customer Code: TunaAustralia C
Your PO No. GloLeads

Bill To:
Tuna Australia Association Ltd.
PO BOX 6
Civic Square ACT 2608

Ship To:
Tuna Australia Association Ltd.
PO BOX 6
Civic Square ACT 2608

PH: 0427-837-966 (David) FAX:
Page 1 of 1
Ship Via | Terms (EXW Mooloolaba) | Prepaid | **Invoice Date:** 12-Apr-21

QTY	Description	Unit Price	Amount AUD
1	2 New Moulds (Lead and Plastic container)	$6,980.00	$6,980.00
10000	Genuine 60-gram GloLead MkII	$0.89	$8,900.00

Comment: **Customer ABN:** 45 613 897 439

Ownership of goods does NOT pass until AFTER payment is received in FULL.
Please pay from this invoice. No statement will be sent.
THANK YOU for your business!!!

Subtotal.:	$15,880.00
Freight:	$0.00
GST:	$1,588.00
Less already received:	$0.00
Total Due AUD:	**$17,468.00**

Figure 2: Full size and cut down lumo leads and quote for production of molds and 10,0000 LL's

Advice is sought from the steering committee on:

1. Research design options
2. Analysis of data collection (meaningful metrics)
3. Interpretation of results
4. **I recommend that this option be funded.**

Sliding weights

A novel solution discussed with one fishing company is the concept of a sliding 60 gram bean sinker, which has been bored out for use on 3.5mm commercial longline. Conceptually, the sliding sinker sits at the hook when the bait is thrown or can be lightly crimped up the line acting in a similar manner to the LL under tension by sliding down the line. This would exceed the current line weighting requirement of 40 grams at the hook, possibly achieving much faster sink rates. This would need to be tested. When a bite off occurs the sinker slips off the line. This concept has been tested in port with video collected to demonstrate the concept.

The seabird mitigation condition suggests weights should be a fixed distance from the hook i.e. 60 grams at a distance of no more than 3.5m. The use of a sliding sinker is potentially at odds with this requirement were the sinker to slide greater than 3.5m away from the hook. The wording of the condition has been changed from “weighted swivel” to weights, but the distance metric remains. The operational reality is that when the bait is thrown it is likely the sinker will be at the hook and will stay there as it sinks through the water column out of reach of bird dives. This exceeds the 40 grams at the hook requirement. Any sliding of the sinker is more likely to occur during the haul. However, the sinker has served its purpose as a mitigation device during the most “at risk” part of fishing operations.

This solution will only work for dead baits and is more likely to be used in deep setting scenarios. This is appears to be a cheap and effective solution which has promise, although uptake by the broader industry is not supported, especially operators using live baits in their fishing strategy.

Figure 3: Modified sliding sinkers

Advice is sought from the steering committee on:

1. Cost benefit of progressing this concept
2. Research design options etc. if relevant

I recommend further discussion around this proposed solution.

Engineered flyback solutions

The current flyback steering committee has been consulted on various options for engineered flyback solutions (flyback bars and flyback screens). There are mixed views of on

1. the efficacy and practicalities,
2. costs and replicability of designs across the fleet due to varying hull and superstructure designs and construction materials.

Previous advice provided by ACAP regarding "flyback" mitigation has centered on the use of sliding weights and PPE, and the use of angled line fighting techniques. PPE is not a practical reasons solution for this problem and the angle that a fish is fought is often determined by the fish itself. Aside from sliding weight solutions (described above), a physical barrier provides another method to manage WHS risk. Approximately 50% (13/23 boats as per Table 3) are supportive of the development of a safety screen and willing to trial if offered the opportunity, while 30% of fishers surveyed believe an engineered safety bar would be a good solution (and were willing to trial). Some operators were concerned by the potential cost of funding their own solution or had difficulty conceptualizing how an engineered bar would reduce the incidence of flybacks.

Flyback bars

The committee has drafted concept designs for physical bars to be fabricated including ballpark costing indicating $6000 worth of materials and another $4000 in labour (fabrication, installation) for a fully engineered solution. Both designs are similar and are based on the existing superstructure on their respective boats. Both designs incorporate a bar constructed of tubular aluminium which can be lowered down from hinged booms and stanchions over the gunwale and cut out area during hauling operations. The concept works by hauling mainline under the bar and playing fish off the snood to the sea door or to the rear of the boat. The bar creates a physical barrier for any "flyback" which will deflect up and away from the danger zone (area immediate above gunwale) where crew are working. The design is based on being folded up and away out of the working area while the boat is underway or not needed for protection.
This is an innovative concept and not known to be in use in any other longline fishery globally. Conceptually, this could be a significant advancement for crew protection from flybacks and a world leading engineering solution if proven successful. Committee members are confident the design will work for their fishing operations and is adaptable to other boat configurations. Feedback from some other fishers is that an engineered flyback bar solution is likely cost prohibitive and may impact on fishing operations (possibly lost fish).

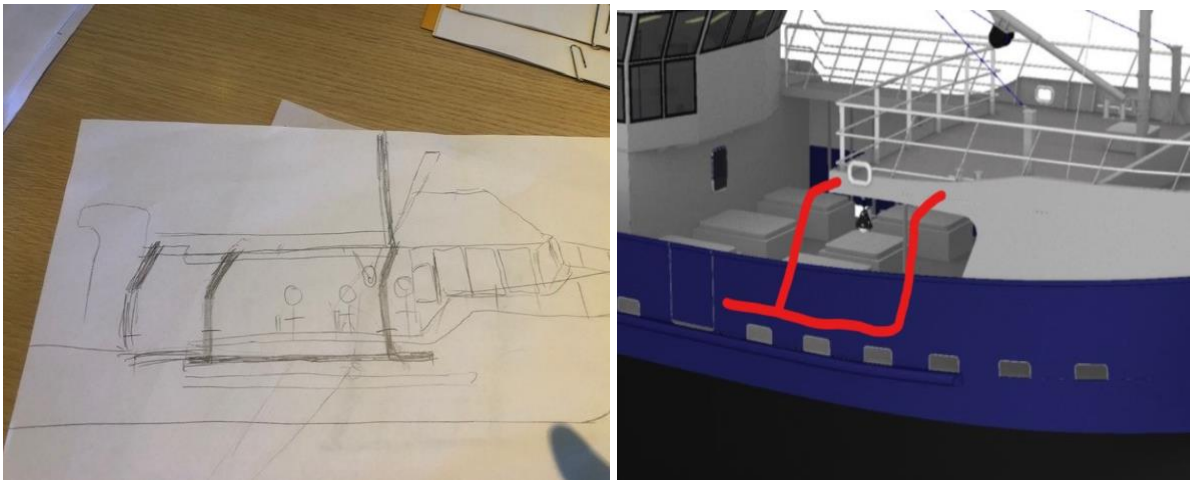


Figure 4: Mock up of potential fly back bar designs

Feedback is sought from the steering committee on:

1. Views on design options and number of devices to test
2. How the designs can be analysed
3. Outputs of the trial
4. **I recommend that the project fund safety roll bar fabrication and installations**

Flyback screens

A committee member has experimented with a screen made from a plastic mesh type material to shield crew from flyback events. Conceptually this looks like it could be a viable solution for those boats that can house the design. Screen characteristics would need to include flexibility, ability to stow when not in use, able to withstand impacts, readily deployable and see through. A "flyscreen" type material, potentially made of a Kevlar / fibreglass composite would be appropriate. Sourcing bulk screening to provide operators (with accompanying instructions) could be a practical solution, if accompanied with appropriate fixings.

Many fishers were interested in the concept of the safety screen and discussed how they could be used on their vessel. The attractiveness lies in the simplicity of the concept and the practical nature of the installation.

This appears to be a simple and relatively cost effective solution that may suit many boats in the fishery. Identifying key construction materials, fixings and installation principles will be the key steps in providing a workable solution.

Figure 5: Mock up of flyback safety screen and Kevlar reinforced fiberglass screening

Advice is sought from the steering committee on:

1. Views on design options and number of units to trial
2. Testing of efficacy of safety screen (controlled environment?) to prove concept
3. Outputs of the trial

I recommend further work to identify key materials and fixings with a view to purchasing enough materials to fit at least 12 boats in the fishery.

Weighted hook solution

The concept of weighted hooks or a combination of lightly weighted hook and lightly weighted swivel have been discussed at length with industry. The industry survey found there was little support for a weighted hook solution or participation in a trial. This is reflected by two boats supportive of trialing a weighted hook, and two other boats interested in outcomes but not willing to participate.

Issues with the weighted hook option include:

1. Some fishers view the concept of a weighted hook to be more dangerous than a weighted swivel in a "tear out" incident. This is because the projectile now has a pointed hook and barb attached to it.
2. While the hook is likely to improve sink rates of baits and seabird protection, it offers nothing in terms of a WHS improvement.
3. Bait performance, longevity, swimming ability and adverse life status through the soak time are all negative considerations.
4. A weighted hook with no swivel will cause snoods to twist under the effect of live baits swimming or when being hauled back to the boat manually or using a snood puller.
5. Weighted hook designs would need to be carefully considered to ensure the gape of the hook is not narrowed, the breadth of the shank is sufficiently thin for hook penetration into bait, and the balance of the hook is not compromised.
6. Weighted hooks may have some efficacy in a dead bait scenario. However, it appears based on interviews that better sink rates can be achieved by a LL or sliding sinker without the dangers of flybacks from tear out incidents.

Weighted hook and swivel combination

1. Conceptually, a lightly weighted hook plus a lightly weighted swivel is more acceptable. However, the same risks remain regarding weighted hook projectile in a "tear out" incident.
2. Lighter weight swivels (~ 25 grams) were once an industry standard but are likely no longer commercially available in the volumes needed for a project. This may be a factor for the project budget if some bespoke manufacturing is required.
3. Similar concerns around live bait performance, longevity etc. still exist, although this is less than for a fully weighted hook design.

Discussion

Fishers are more concerned about catch rates and live bait performance than they are about weighted hooks providing improved seabird protections. They acknowledge that there are potential advantages for sink rate and bird mitigation, but there are other solutions to this problem that will not have as great an impact on their ability to catch fish.

There is lukewarm support from some fishers in Ulladulla to conduct a short term trial of a weighted hook and swivel combination. However they may participate if several boats are involved using the trial gear on the same trips. In that way each fisher is “equally disadvantaged” for that trip.
Production of an appropriately designed and weighted hook still requires consideration. Hook manufacturers will only do a bespoke production run based on a minimum order of 10,000 hooks.

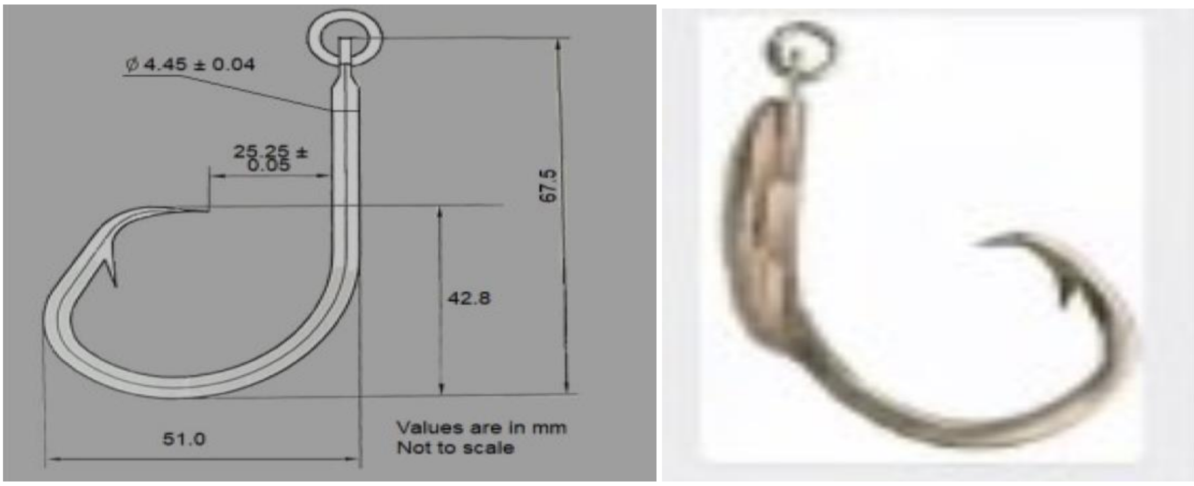


Figure 6: Conceptualised weighted hook design and possible dimensions

Advice is sought from the steering committee on:

1. Research design options (no. of hooks, use of TDR’s etc.)
2. Analysis of data collection (meaningful metrics)
3. Interpretation of results

I recommend that we progress to developing a run of weighted hooks for this project and design sea trials around a short term deployment. Testing sink rate efficacy and resulting bait performance may provide some positive outcomes which may then inform further trialing.

Side setting

To address this project option the current and ex owners of the Fisco 1 – the only boat currently side setting in the ETBF were consuted. Further discussions were also conducted with the Hawaiian longline fishery industry association.
Side setting as alternate solution for WHS and seabird mitigation improvements was poorly received by every fisher consulted. The main concerns were that

1. side setting offered no additional safety improvements, and
2. any gains for seabird protection were not worth the effort and cost to reconfigure their boat as these are currently being met by mitigation methods

Even the current owner would prefer to set from the stern if the boat design would allow.
The key issues raised by the current owner are as follows:

1. Fishing beam on to the sea in rough weather makes the boat very wet and unstable. This could be alleviated by having another cutout on the starboard side of the boat to provide another hauling option, but this would require either placing additional blocks into the shooting set up which would add more strain to the mainline.
2. Side setting on the boat requires baits to be thrown straight from the bin, which results in more bin tangles and snoods are often thrown “over” the mainline if not careful.

3. Unable to use a line shooter because of the way the boat is currently configured; this reduces the ability to vary shooting speeds to get optimum slack in the line to get baits sinking deeper and faster.
4. Snoods and bubbles often go under the boat which can cause propellor fouling if not managed carefully.
5. Increased gear tangling is resulting in greater gear losses and maintenance. This appears to be 50% greater than stern setting.

Some “side setting positives” were discussed:

1. There are advantages for seabird mitigation. They have a very good record with seabird interactions and this is because they have very few birds attracted to the bait setting area. The baits are well sunk by the time they have reached the stern of the boat.
2. There are efficiencies when setting the gear. They feel they can shoot a lot faster than other boats because of the way the crew are placed adjacent to the mainline
3. The skipper has full visibility of the working area of the boat as it is a raised aft wheelhouse and he can see the whole shooting station and cut out area for the haul.

Discussions with the previous owner of the Fisco 1 showed a deeper level of understanding of the side setting method given they owned the boat for 20 years. The following issues were discussed in the context of safety and improved seabird protections:

1. The Fisco 1 was previously configured to set from both sides of the boat. This was achieved by placing another block under the shelter cutout on the forward starboard side. However, it was infrequently used but did provide an alternative if the sea state and weather conditions made it impossible to shoot from the port side.
2. Regardless of the shooting side the boat was particularly wet and the crew “copped a flogging” on every shot in any sort of beam on sea.
3. When setting it was important for two crew to be working out of one bin. One crew member threw the bait while the other threw the swivel. The tangles experienced by the current owner do not reflect the experience of the previous owner.
4. While a line shooter was unable to be used, upon reflection any slack in the mainline was more likely to cause issues with the mainline potentially fouling the propeller. The previous owner found there was a need to maintain a lot more control over the direction of the boat to avoid prop fouling from the mainline and snoods.

The positive commentary about the advantages of side setting and seabird mitigation were reflected by the previous owner. They had an exceptionally good record with seabird interactions over a sustained period of time.

Discussions with Hawaiian longline fishery industry association

During the development of this discussion paper, Tuna Australia was contacted by the Hawaiian Longline Fishery Industry Association (HLA) to consult on potential options for reducing flybacks and other commonalities between the fisheries. The fishery is transitioning away from steel traces in response to declining Oceanic Whitetip Shark stocks (listed under US Endangered Species Act) as a proactive initiative. As well as discussing this proposed solutions in this project, a number of key questions were asked relating to side setting and the key differences between the Hawaiian and Australian longline fishery experience.

1. Are there environmental factors that make it easier to side set in the Hawaiian fishery? (e.g. is there a prevailing wind pattern, are they working sheltered waters, is the current and eddy structure conducive to consistent fishing speed and direction etc.). Oceanic conditions are not dissimilar to Australian waters, the fleet is generally nomadic out to 1000nm from Hawaii. There are spatial closures inside 60nm to protect turtles which means no access to (relatively) near shore oceanic conditions. General feedback is that there are no real safety issues with side setting, although some vessels have returned to set from the stern to provide more comfort for crew.
2. What were the drivers for transitioning to side setting in the Hawaiian fishery and are those drivers relevant to the Australian fishing experience? Work done testing underwater bait setters and side setting was part of a broader strategy to improve seabird mitigations. Prior to 2006 several seabird deterrent measures were in place for the fishery i.e. blue dyed baits, line weighting etc. The US government allowed side setting, in lieu of some of the other mitigations for boats working north of 23°N as the primary seabird mitigation. A lot of boats transitioned to side setting at that time to give them more mitigation options when working in that area.
3. Are there different seabird species, migration patterns and behaviors between the two fisheries and is this reasonable grounds for suggesting the solution lies in side setting? The Hawaiian experience is that the main bird species (Black Footed what?, Laysan Albatross, Northern Fulmars) have different foraging habits to Australian birds. They are not deep diving birds and the main risk is from baits taken on the surface when setting. Transitioning to side setting may not be a panacea for seabird protection if the species experienced in Australian waters are able to dive to greater depths to attack baits.
4. Do we have the same safety issues as Hawaiian longline fishers? There are a number of similarities especially now the Hawaiian fishery is transitioning to mono leaders, so flybacks will be part of the thinking on safety management systems. Work has been done on a sliding sinker solution sleeved with clear plastic on the mono, and a safety chain system but these are in early development.
5. Has there been any work done on with changing line shooter settings v boat speed settings to assist sink rates in the Hawaiian fishery? No, a general rule of thumb is that line shooter speeds are set a 1.3 x boat setting speed with side setting boats a good sink rate is being achieved, so experimentation with these things has not been explored.
6. What are your views on weighted hooks as a concept and can you see benefits to using these as a seabird mitigation strategy? The concept has merit but there are safety concerns about the hook potentially becoming a projectile in a tear out situation. Those concerns are probably less now the transition to mono is occurring (as bite offs will now become the greater cause of flybacks). Weighted hooks may be useful in a deep setting Bigeye fishery.

The meeting with the HLA provided some interesting perspectives. Converting a boat to side setting is not something that any Australian skipper is willing to consider for this project. There was less concern from the HLA about the safety aspects of side setting. From a seabird protection standpoint there are some clear benefits, but there are other ways of managing seabird interactions on stern setting boats.

The project steering committee needs to consider the efficacy of side setting in the context of other mitigations and safety options available to boats. While not discounting the positive aspects of side setting, there are several considerations about the Australian fishery that do differ from the Hawaiian longline fishery which need to be worked through.
I recommend further discussion on this proposed solution.

Appendix 2 - Tori line data collection sheet

Tuna Australia Tori Line Data Collection Sheet

Tori line data collection sheet

Name of Boat / date of trip: ____

Tori Line design (A or B)	Information required	Description	Answer
Tori details	**Which tori line has been deployed?**	Regular tori line (A) 7m tori line (B)	
Shot details	**Date / trip number**	Self explanatory	
	Time of deployment (start of shot)	Self explanatory	
	Time of retrieval (end of shot)	Self explanatory	
	Latitude band	(25 – 30°) (30 – 35°) (35 – 40°) (40 – 45°)	
Setting details	**Boat setting speed**	Speed of vessel	
	Line shooter setting speed	(knots)	
	Seconds per hook	Interval rate (s)	
	Sink rate	Estimated (meters/second)	
	Bait type used	Squid / pilchard, live Yellowtail etc	
Environment	**Environmental conditions (sun / cloud cover / precipitation)**	Observed / predicted environmental conditions	
	Wind details (direction / relative to boat / strength)	Observed / predicted wind conditions	
	Sea state / swell	Observed / predicted sea state / swell conditions	

Seabird details	**Bird abundance (est.)**	Bird count in the general area	
	Species	Describe each bird type and estimated numbers of each type	
	Bird behavior e.g. following, foraging, attacking baits, competition	Describe what the birds are doing e.g., general foraging, attacking baits, competing	
	Seabird interactions	(As reported to AFMA)	
Tori line performance	**Ease of deployment**	Were there tangles, did the droppers get caught or wrapped around themselves? etc.	
	Aerial performance	Does tori line keep shape when towed	
	Estimated aerial extent (m)	Distance to where tori line enters water.	
	Efficacy	Describe bird reaction to tori line	
	Number of hook ups per shot	Record any hook ups that occur	
	Reason for hook up	Describe how the hook up occurred	

General comments (performance, improvement advice etc.):

Appendix 3- Bermagui seabird interactions Tori line review

A review of tori line performance in response to recent seabird interactions

TUNA AUSTRALIA

[redacted] tori line review – FRDC 2020-041

I attended FV [redacted] on 6 June 2022 to conduct a review of tori line performance in response to recent seabird interactions.

In the lead up to this visit, I consulted with Nigel Brothers about options for making some alterations to the tori lines to address concerns about aerial extent, effectiveness, and ease of handling.

The tori lines appeared to work reasonably well in sea conditions less than 15 knots. However, there was a need to improve performance in adverse sea states and address concerns of aerial extent, and the "drogue" portion becoming tangled in the prop (this was the cause of one tori line being damaged, since replaced).

The following modifications were made to both tori lines:

1. For both Tori Line Type A and Type B, 150m of drogue line was removed from the design.
2. A loop was crimped into the end of each drogue line to create an attachment point for additional accessories.
3. A removeable drogue system was developed using a shark clip, branch line, a sliding lead, funnel, float and stopper rings.

Additional modification for Type B tori line:

1. Removed the last 4 "short droppers" (closest to waterline) to remove excess weight from the tori line to increase aerial extent.
2. Added three sliding leads near the end of the drogue line to help shape the line in the air.

Sea trials

A short trip was conducted ex Bermagui harbor to deploy both tori lines and assess design improvements. A home made measuring device was fabricated using handline reel, 200m of 100lb monofilament with a float and stopper placed at the end. Fluorescent tubing was placed at 10m intervals to measure aerial extent. Once the tori lines were fully deployed and "shaped", the measuring device was unwound until the float was even with the entry point of the tori line to the water. The device was then retrieved counting back the number of fluorescent tubes.

Sea conditions were poor, with a 2m Easterly swell and winds to 50km/hr from the West

Tori Line A obtained aerial extent of 95-100m and Tori Line B 65 – 70m. The following improvements were noted:

1. The skipper noted both tori lines looked substantially better in action.
2. While the aerial extent of Type B was less, the more rigid dropper material gave good coverage of the danger areas closer to the boat.
3. Removing the last 4 droppers of Tori Line B gave the tori line more "loft", contributing to better overall shape of the tori line
4. The removeable drogue system created very regular large splashes in the water. While this created momentary distortion of the tori line shape, the "explosions" will add an additional scaring element to birds following the boat or foraging behind the tori line.

Overall, the design changes will improve the performance of tori lines. Feedback is currently being sought from other trial participants from their experience and to make modifications where necessary as the tori line design maybe vessel specific.

Discussion

The current scientific permit conditions state that:

Gear Limitation

12. This scientific permit authorises the use of the following gear only:
    a. Tori line with either of the following specifications
        i. monofilament backbone, 100m in length with 200m of trailing mono as a drogue. The drogue is supplemented with a detachable "lumo snake" which can be added / removed / shortened depending on sea state. The dropper material consists of doubled up lengths of "packing tape" of various vibrant colors crimped into the system in alternating long (to the water line) and short (1m) lengths at 3m intervals.
        ii. Sekiyama backbone, 100m in length with 200m of trailing Sekiyama as a drogue. The drogue is supplemented with a detachable weight or "lumo snake". The dropper material consists of doubled up lengths of "Beautori" rubber tubing in lengths to maintain contact with the water at 5m intervals. The dropper material is attached via a "crane swivel" system to remove tangle points out of the system.

The modifications made to the tori lines on [redacted] are now inconsistent with the gear limitations set in the Scientific Permit regarding the "trailing 200m of mono / Sekiyama" portion of the tori line.

To facilitate the operational improvements made to the tori lines on [redacted] (or other boats who may wish to instigate these improvements), suggest the wording in the gear modification section of the Scientific Permit be changed to:

i. Monofilament backbone 100m in length, with ***up to*** 200m of trailing mono as a drogue. ***The drogue can be supplemented with additional weights or accessories to assist in the performance of the device.***

ii. Sekiyama backbone 100m in length, with ***up to*** 200m of trailing Sekiyama as a drogue. ***The drogue can be supplemented with additional weights or accessories to assist in the performance of the device.***

The modifications made to Type B tori line, in my interpretation, are still consistent with ACAP best practice recommendations for boats <35m in length, with Type A tori line well exceeding the specifications. Key elements of the ACAP BP advice are that long droppers are spaced at no greater than 5m intervals over the first 55m of the tori line. Type B tori line still includes long droppers x 10 down to the last 45m of the tori line.

Picture 1: Tori line extent measuring device and fabricated drogue attachments

Picture 2: Aerial extent of Type A (L) and Type B tori lines (R)

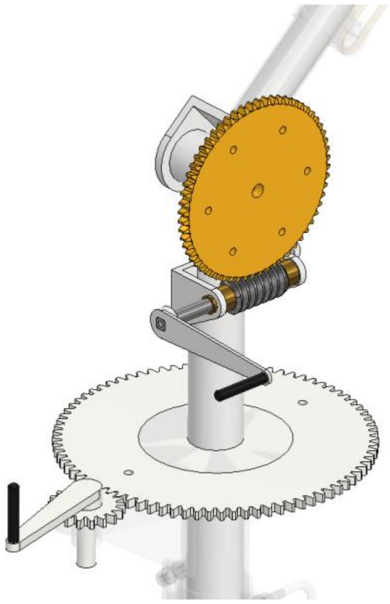
Phil Ravanello

Program Manager

Tuna Australia

Appendix 4 -Engineering report Adaptive Tori Line system

Engineering design report – Adaptive tori line development



This is a Commercial – in – Confidence report.
For further details contact

Mr. Tyler Krause
Australian Maritime College
PO Box 2036, Newnham TAS 7248
e - tyler.krause@utas.edu.au
www.amcsearch.com.au

Appendix 5 - SLL data collection sheet

Shortened Lumo Leads - Data collection sheet

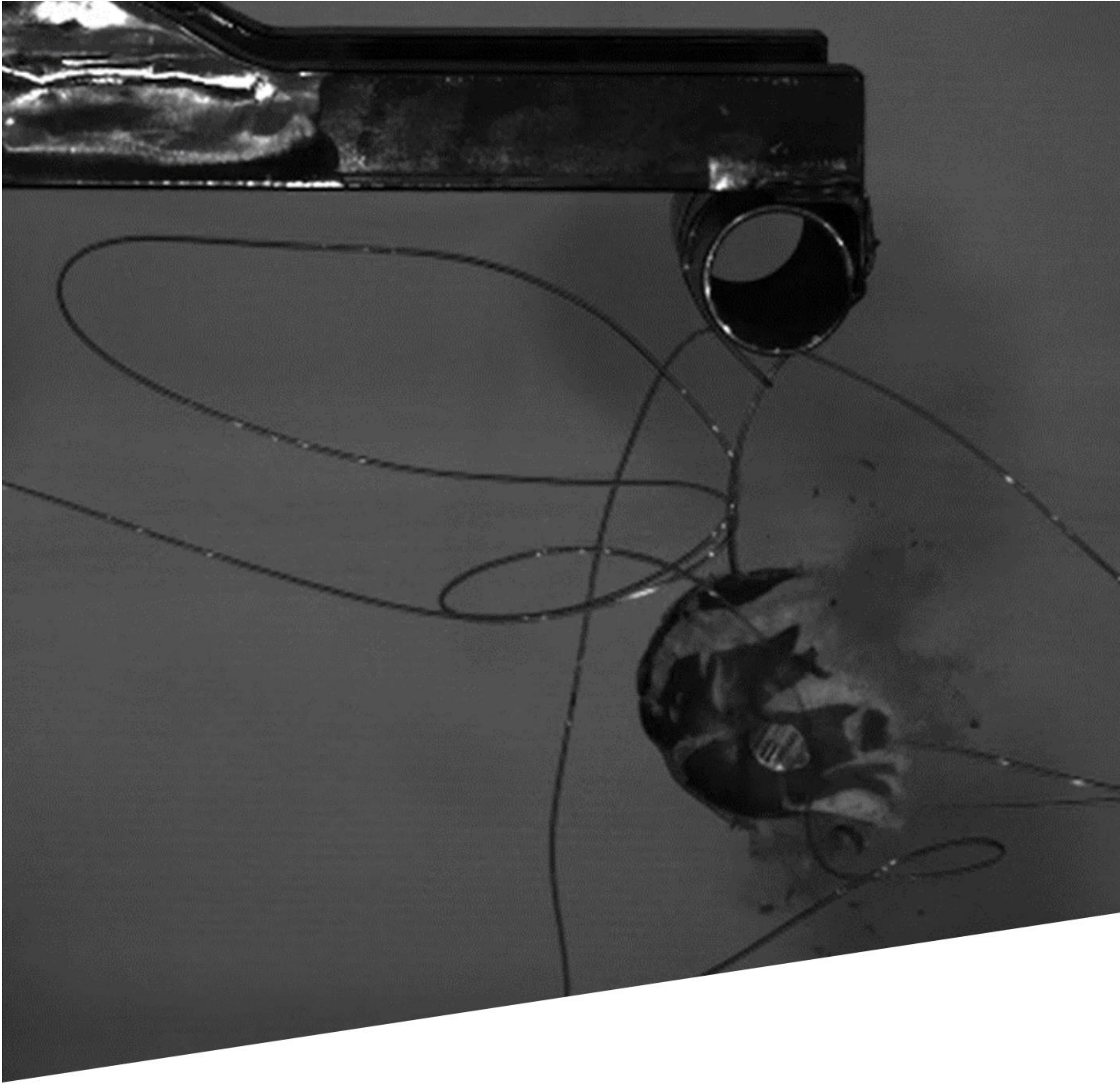
Shortened safety lead data collection sheet

	Information required	Description	Answer
Boat details	Name of boat		
	Date of trip		
	Number of shots		
	Number of hooks per shot		
Setting details	Boat setting speed	Speed of vessel	
	Line shooter setting speed	Speed line shooter is set at	
	Seconds per hook	Interval rate that hooks are thrown	
	Sink rate	Estimated	
	Bait type used	Squid / pilchard, live Yellowtail etc	
SLL performance	Ease of deployment	Number of bin tangles per shot	
	Distance SLL to hook	Estimate distance from weight to hook – is all gear made the same?	
	Number of flybacks for trip	How many flybacks did you have during the trip?	
	Number of "near misses" for trip	Number	
	Reasons for near misses	E.g. shark bite off, tear out	

General comments: You may wish to expand on any incidents that occurred while using the shortened lumo leads e.g. bite offs where the lead slid into the water, mitigating risk or injury, any suggested design improvements:

Appendix 6 - Flyback Simulation Project Part 1

Fishing Line Flyback Simulation August 2023 – Part I



REPORT

FISHING LINE FLYBACK SIMULATION PROJECT

AUGUST 2023

AMCS AMC SEARCH

Training and Consultancy Division of the Australian Maritime College

Document Control Sheet

AMC Search Ltd Maritime Way Newnham Tasmania 7248 Australia Tel: +61 36324 9850 Locked Bag 1400, Launceston, Tasmania, 7250, Australia www.amcsearch.com.au	Reference Number:	23/G/11
	Title:	Fishing Line Flyback Simulation Project
	Report Author/s:	Dr Tom Mitchell Ferguson Dr Roberto Ojeda Dr Nick Rawlinson
	Client:	Tuna Australia
	Client Contact:	Mr Phil Ravanello
	Client Reference:	12252764443
Project Summary:	An experimental study was undertaken by AMC Search Ltd. on behalf of Tuna Australia, to observe and measure the velocity and impact location of flyback events occurring in pelagic longline branchlines equipped with four different weighting designs to reduce seabird interactions that are currently in use or being tested by Australian fishing vessels.	

Revision Checking History

Revision Number	Revision Type (Draft or Final)	Date	Checked by
0.1	Draft	25/08/2023	Nic Bender
		Click or tap to enter a date.	
		Click or tap to enter a date.	

Distribution

Destination of Document	Version*										
Mr Phil Ravanello AMC Search File Library	0	1	2	3	4	5	6	7	8	9	10

NB: Version listed for Final Report only

Third Party Disclaimer

Any disclosure of this report to a third party is subject to this disclaimer. The report was prepared by AMC Search at the instruction of, and for use by, our client named on this Document Control Sheet. It does not in any way constitute advice to any third party who is able to access it by any means. AMC Search excludes to the fullest extent lawfully permitted all liability whatsoever for any loss or damage howsoever arising from reliance on the contents of this report.

Lead Author

Name	Signature	Date
		Click or tap to enter a date.

Report Released By

Name	Signature	Date
		Click or tap to enter a date.

Contents

List of figures

List of tables

Introduction

An experimental study was undertaken by AMC Search Ltd. on behalf of Tuna Australia, to observe and measure the velocity and impact location of flyback events occurring in pelagic longline branchlines equipped with four different weighting designs to reduce seabird interactions that are currently in use or being tested by Australian fishing vessels. Additionally, the study investigated the change in velocity and impact location when these branchlines are tensioned under a safety bar.

Methodology

2.1. Experimental setup

The present study was conducted at the AMC Thermodynamics Laboratory Workshop using the bespoke flyback simulation test setup shown in Figure 1. The flyback simulation setup was designed to provide constant tension to all tested fishing line setups.

The hook end of each monofilament longline branch arrangement, described in Section 2.2, was connected to a trigger mechanism located at the tip of a forklift tine positioned outside the workshop space. The other end of the monofilament line was attached to a 76.64 kg mass (M) through a pulley located atop of the tensioning frame. Tension on the line was achieved by reversing the forklift until the mass M lifted off the ground as shown in the diagram below. The trigger mechanism used a cable-actuated snap shackle to release the hook when the desired tension was achieved.

Two configurations were investigated:

A **standard** configuration where the monofilament line was stretched directly from the trigger mechanism to the tensioning frame pulley.

A **safety bar** configuration where the monofilament line was stretched from the trigger mechanism to the tensioning frame pulley whilst passing under a 50 mm diameter round bar located 0.8 m ahead and bellow the tensioning frame pulley.

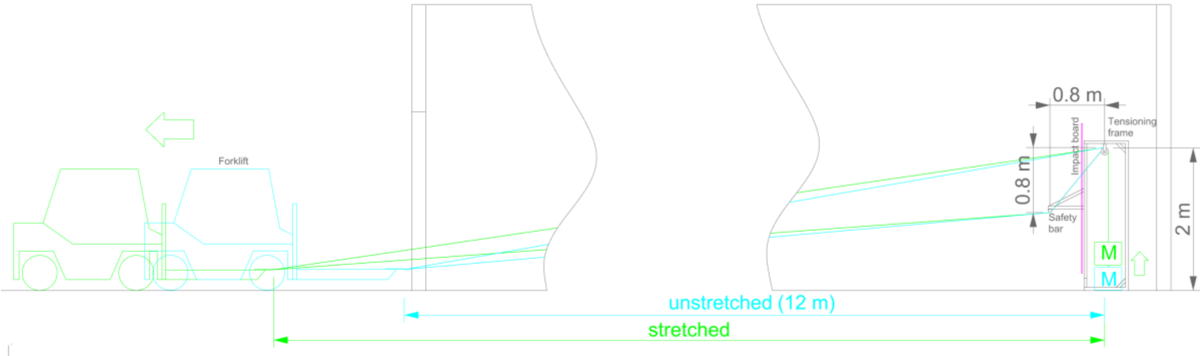


Figure 1: Experimental setup diagram

An impact MDF board was attached to the front of the tensioning frame to slow down the projectiles. A slit was machined in the board to allow the wiring of the monofilament line through the tensioning frame pulley. The point at which the monofilament line passed through the impact board was set as the datum for all position calculations reported in Section 3 of this report.

2.2. Tested branchline arrangements

All branchlines were 14 m long and constructed of 1.8 mm clear Fujiyama nylon monofilament. The arrangements to test the different branchline weighting designs were:

Hook and Swivel (Standard gear)

The branchline was comprised of two sections of monofilament line with the upper section representing the hauling end being 10.5m and the lower section the end of the branchline being 3.5m from the hook. The two sections were joined by crimping the line through the fixed weight swivels using 2 x E-size alloy single crimps. The monofilament loops were covered by anti-chafe soft nylon sleeving to minimise breakage around these joints. The hook attacked to the end of the branchline was a 13/0 forged Stainless Steel (4.2mm) offset circle hook with ring. The small loop used as the attachment point for the test weight was swaged using 2 crimps. The 60g stainless leaded fixed weight swivel, shown in Figure 2, was set 3.5m from the hook.

Figure 2: Hook and Swivel.

Procella Weighted Hook

The Procella weighted hook, shown in Figure 3, consists of a 34g weight welded to 16g “cetacean friendly” (4.5mm maximum diameter hook gauge) 16/0 circle hook. The Procella weighted hook was attached directly to the end of the 14m branchline using a swage and anti-chafe connection to ring on hook. The small loop used as the attachment point to the test weight was swaged using 2 crimps.

Figure 3: Procella weighted hook.

GloLead MkII Short Sliding Safety Lead

The GloLead MkII Short Sliding Safety Lead, shown in Figure 4, was set 1.5m from the hook using hand tensioning. The monofilament branchline was threaded directly through the sliding lead. The hook attacked to the end of the branchline was a 13/0 forged Stainless Steel (4.2mm) offset circle hook with ring. The small loop used as the attachment point for the test weight was swaged using 2 crimps.

Figure 4: Sliding safety.

Hookpod mini

Hookpod Mini (Figure 5) is constructed of two plastic sections that are hinged together. A white plastic collar at the top of the Hookpod is twisted to secure the device in position after it is attached to the branchline. During these experiments, the Hookpods were set in an open-state to simulate the expected situation during the hauling of a branchline, when fly-backs occur.

The Hookpod mini were set 1.0m from the hook in the 'open' position. The monofilament branchline was threaded directly through the Hookpod mini. The hook attacked to the end of the branchline was a 13/0 forged Stainless Steel (4.2mm) offset circle hook with ring. The small loop used as the attachment point to the test weight was swaged using 2 crimps.

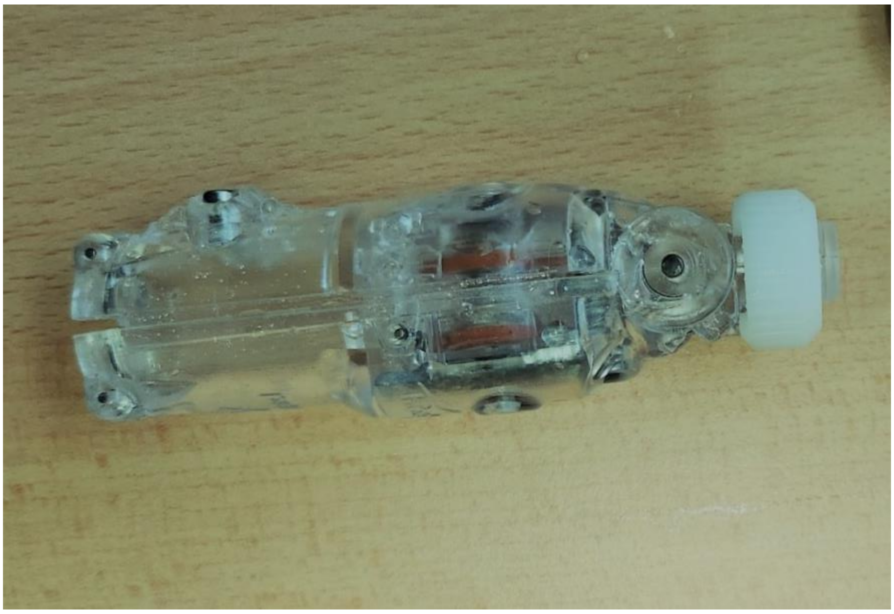


Figure 5: Hookpod mini.

2.3. High-speed camera setup

Two Photron FASTCAM S-AZ 2100K cameras were utilised to capture high speed images of the flyback impacts against the MDF impact board.
The cameras were mounted on an 80/20 aluminium extrusion spreader beam fixed atop a heavy-duty metrology tripod. The tripod was positioned behind protective polycarbonate screens shooting approximately perpendicular to the flyback direction as shown in Figure 6.
A 647 mm spacing between the cameras was chosen to achieve the recommended horizontal shooting angle difference between the two cameras of approximately 15 degrees at the expected point of impact.

Figure 6: High-Speed camera setup
The target area was illuminated using four MEC MULTI LED QX and two NILA VARSA high power LED lights.

2.4. DIC calibration

The cameras were calibrated using a laser etched aluminium calibration target as shown in Figure 6 using a 2nd order radial calibration using 47 and 41 image pairs for the lower and upper camera positions respectively.

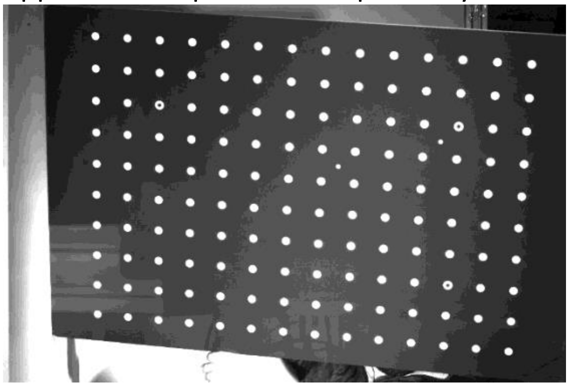


Figure 7: Calibration of the cameras was performed using a calibration target.

The camera height was set to capture the impact for the two set-ups (standard and safety bar) as shown in Figure 7 and 8. Image pairs were captured at a frame rate of 30,000 fps with a resolution of 1024 x 688.

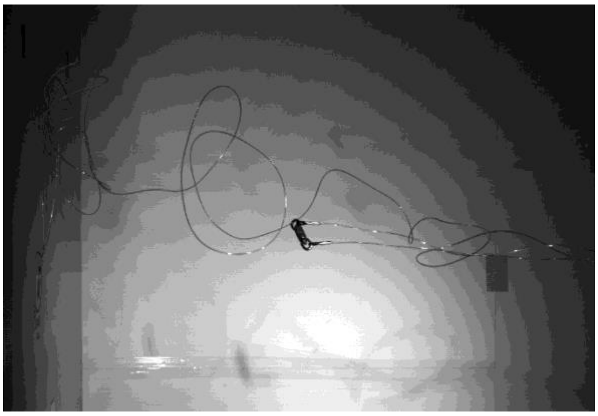
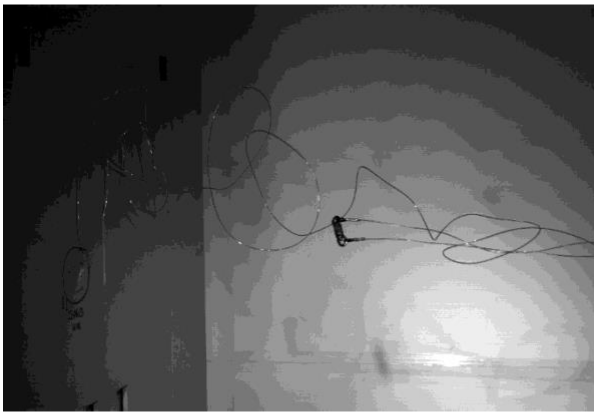



Figure 8: Image pairs from upper camera position for standard tests.

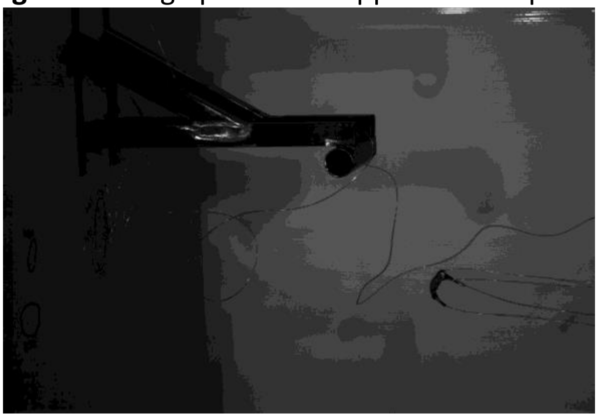



Figure 9: Image pairs from lower camera position for safety bar tests.

2.5. DIC image processing

The images were post processed using VIC-3D Digital Image Correlation software. Markers were manually identified to determine the position and velocity of the key object identified in each line arrangement. Two markers were tracked on each of the identified arrangement to account for rotation as shown in Figure 9. The position of the markers was determined in three dimensions and then corrected according to the datum.

The velocity was calculated using:

$$V_{x,y,z} = \frac{P_{1(x,y,z)} - P_{0(x,y,z)}}{t_1 - t_0}$$

Where V is the velocity in mm/s, P is the position in mm and t is the time in seconds. To account for rotation, the reported velocity of each run is the average of the two identified points. It was assumed there was negligible change in velocity over the distance measured. The impact location was calculated by projecting the velocity until it reached the MDF impact board.

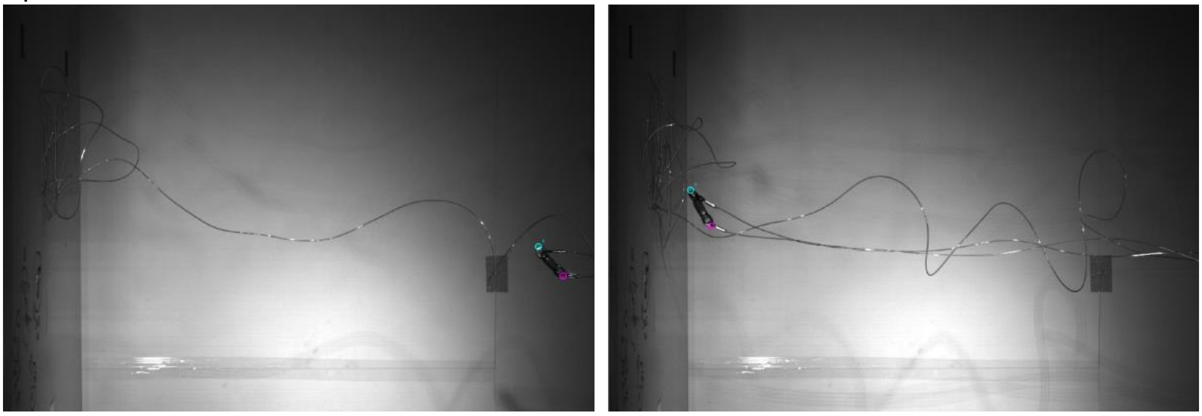


Figure 10: Images demonstrating the tracking of the swivel[1]

[1] Note the tracking of two points (in magenta and cyan) to account for changes in the orientation of the swivel during its flight.

Results

A total of 45 runs were completed, 22 in the standard configuration and 23 with the safety bar. A summary of the results of the testing is presented in Table 1.

For each result, the following parameters are provided:

Run – test number

Configuration – Standard or Safety bar

Branchline arrangement – Procella, Hook & Swivel, Sliding safety or Hookpod mini

Velocity – measured velocity

In mm/s

In km/hr

Impact location – position of the impact at the MDF impact board relative to the datum

Y – horizontal location in mm

Z – vertical location in mm

Force Max – maximum force measured during impact

Notes – any other relevant information

For velocity/impact the measurement of velocity and impact location refers to (unless otherwise noted):

Procella - Hook

Hook & Swivel - Swivel

Sliding safety - Sliding safety

Hookpod mini -Hook

Where the impact occurred outside of the field of view of the camera, no velocity or impact position data has been provided. Additional notes for these runs have been provided where possible. A graphical representation of the impact location distribution for both the standard and the safety bar configurations are provided in Figure 11 and Figure 12 respectively.

Run 22 was performed with a protective curtain for visualisation purposes only. No velocity data is presented for this run. The high-speed video of this impact suggests that a protective curtain may be a viable alternative to reduce flyback impact velocities. It is suggested that further experiments are conducted to confirm this hypothesis.

Run 45 was performed to illustrate the damage generated by a flyback impact by striking an apple with a hook and swivel branchline arrangement.

Table 1: Summary of testing results

					Impact Location		
Run	**Configuration**	**Branchline Arrangement**	**Velocity [mm/s]**	**Velocity [km/hr]**	**Y [mm]**	**Z [mm]**	**Notes**
1	Standard	Procella	65169	234.6	-113	-113	
2	Standard	Hook & Swivel	58721	211.4	-9	-9	
3	Standard	Sliding safety	42202	151.9	-289	-289	
4	Standard	Procella	64702	232.9	-158	-158	
5	Standard	Hookpod mini	70073	252.3	-91	-91	Hookpod mini broken, hook measured
6	Standard	Hook & Swivel	59198	213.1	-4	-4	
7	Standard	Sliding safety	46814	168.5	-288	-288	
8	Standard	Hookpod mini	-	-	-	-	Impact out of frame (below)
9	Standard	Procella	67410	242.7	-242	-242	
10	Standard	Hook & Swivel	59709	215.0	16	16	
11	Standard	Sliding safety	43742	157.5	-207	-207	
12	Standard	Hookpod mini	89753	323.1	30	30	Hookpod mini broken
13	Standard	Procella	62985	226.7	-89	-89	
14	Standard	Procella	68012	244.8	207	207	
15	Standard	Hook & Swivel	57155	205.8	-19	-19	
16	Standard	Sliding safety	83806	301.7	336	336	Hook sheared off line, hook measured
17	Standard	Hookpod mini	-	-	-	-	Hook sheared off line, hook out of frame
18	Standard	Hook & Swivel	59695	214.9	-1	-1	
19	Standard	Procella	69274	249.4	-147	-147	
20	Standard	Sliding safety	-	-	-	-	Hook and slider impact out of frame
21	Standard	Hookpod mini	-	-	-	-	Hook sheared off line, hook out of frame
22	Standard	Hook & Swivel	-	-	-	-	Curtain impact, no velocity measured
23	Safety Bar	Hook & Swivel	61552	221.6	-760	-810	
24	Safety Bar	Hook & Swivel	60819	218.9	-707	-757	

25	Safety Bar	Hook & Swivel	61477	221.3	-755	-805	
26	Safety Bar	Hook & Swivel	63485	228.5	-723	-773	
27	Safety Bar	Hook & Swivel	58667	211.2	-786	-836	
28	Safety Bar	Procella	67511	243.0	-503	-553	
29	Safety Bar	Procella	69156	249.0	-470	-520	
30	Safety Bar	Procella	71998	259.2	-464	-514	
31	Safety Bar	Procella	71481	257.3	-450	-500	
32	Safety Bar	Procella	-	-	-	-	Early release
33	Safety Bar	Procella	69645	250.7	-653	-703	
34	Safety Bar	Hookpod mini	-	-	-	-	Hook sheared off line, hook out of frame
35	Safety Bar	Hookpod mini	73994	266.4	-768	-818	Hookpod mini broken
36	Safety Bar	Hookpod mini	65875	237.2	-790	-840	Hookpod mini broken
37	Safety Bar	Hookpod mini	82038	295.3	-756	-806	Hook sheared off line
38	Safety Bar	Hookpod mini	61405	221.1	-631	-681	Hook sheared off line
39	Safety Bar	Sliding safety	46266	166.6	-885	-935	
40	Safety Bar	Sliding safety	44413	159.9	-859	-909	
41	Safety Bar	Sliding safety	-	-	-	-	Early release
42	Safety Bar	Sliding safety	95663	344.4	-631	-681	Hook sheared off line, hook measured
43	Safety Bar	Sliding safety	92151	331.7	-682	-732	Hook sheared off line, hook measured
44	Safety Bar	Sliding safety	110540	397.9	-682	-732	Hook sheared off line, hook measured
45	Safety Bar	Hook & Swivel	-	-	-	-	Apple impact test.

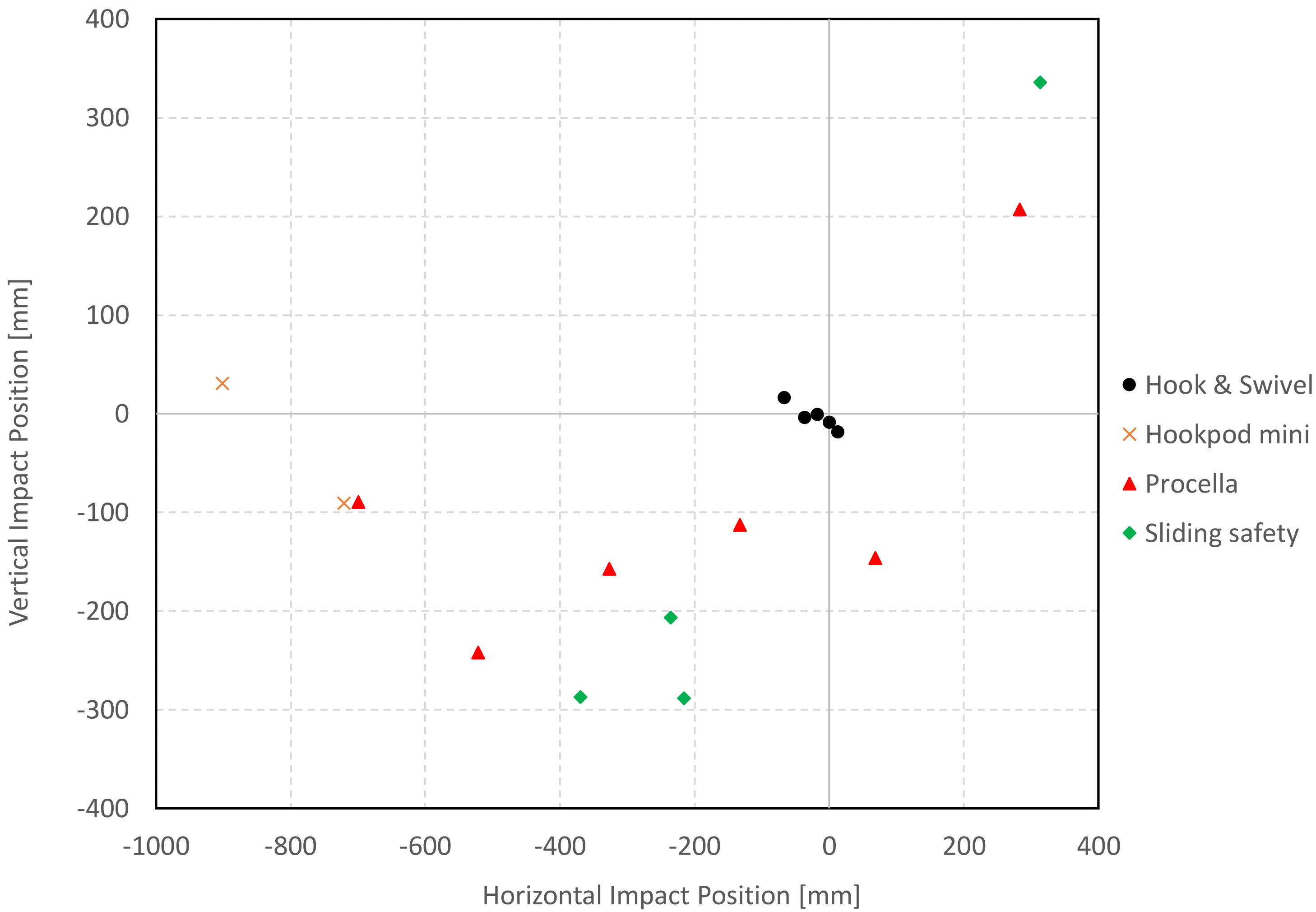


Figure 11: Impact position for the standard configuration

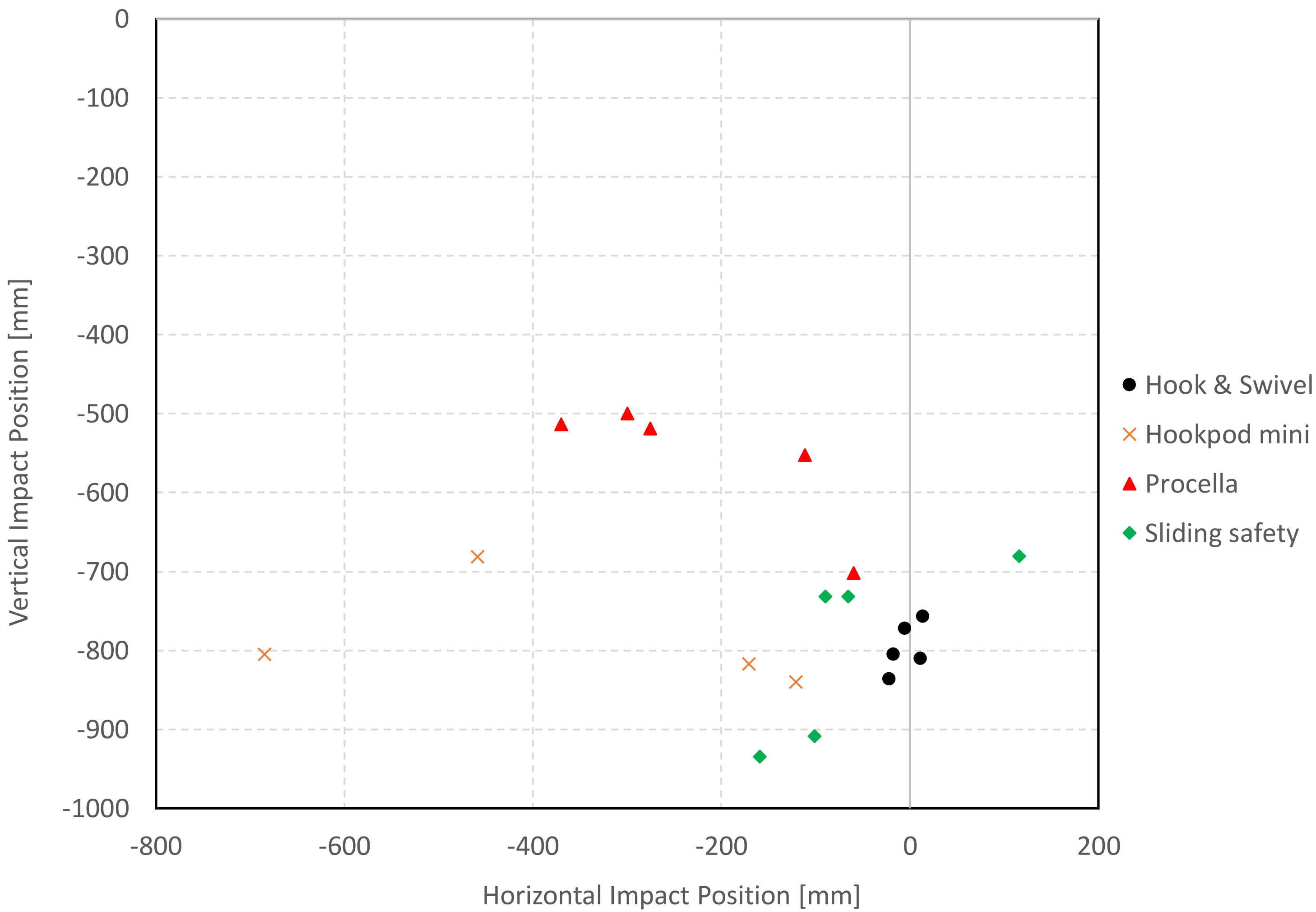


Figure 12: Impact position for the safety bar configuration

Appendices

This report includes the following digital appendices:
High-speed video of each test
Excel file containing a summary of results.

Appendix 7 - Flyback Simulation Project Part II

Fishing Line Flyback Simulation August 2024 – Part II

REPORT: 24.G.15

TUNA AUSTRALIA: FISHING LINE SIMULATION PROJECT - PART II

AUGUST, 2024

AMCS AMC SEARCH

Training and Consultancy Division of the Australian Maritime College

Document Control Sheet

<table>
<tr><td rowspan="6">AMC Search Ltd
Maritime Way
Newnham Tasmania 7248
Australia
Tel: +61 36324 9850
Locked Bag 1400,
Launceston TAS 7250
Australia
www.amcsearch.com.au</td><td>Reference Number:</td><td>24.G.15</td></tr>
<tr><td>Title:</td><td>Fishing Line Flyback Simulation Project – Part II</td></tr>
<tr><td>Report Author/s:</td><td>Dr Tom Mitchell Ferguson
Dr Roberto Ojeda</td></tr>
<tr><td>Client:</td><td>Tuna Australia</td></tr>
<tr><td>Client Contact:</td><td>Mr Phil Ravanello</td></tr>
<tr><td>Client Reference:</td><td></td></tr>
<tr><td>Project Summary:</td><td colspan="2">Branchline Flyback Experiments carried out in AMC's Thermolab Workshop space, utilising UCRF high-speed cameras/DIC system, combined with a bespoke test frame and protection screens.</td></tr>
</table>

Revision Checking History

Revision Number	Revision Type (Draft or Final)	Date	Checked by
2	Final	5 Sept 2024	Chris White

Distribution

Destination of Document	Version										
Mr Phil Ravanello	0	1	2	3	4	5	6	7	8	9	10
AMC Search File Library			X								

Lead Author

Name	Signature	Date
Dr Thomas Mitchell Ferguson		19/08/2024

Report Released By

Name	Signature	Date
Chris White		5/09/2024

Contents

List of figures

List of Tables

1.Introduction

An experimental study was undertaken by AMC Search Ltd. on behalf of Tuna Australia, to observe and measure the velocity and impact location of flyback events occurring in pelagic longline branchlines equipped with four different weighting designs to reduce seabird interactions that are currently in use or being tested by Australian fishing vessels.

The study also investigated the change in velocity and impact location when these branchlines are tensioned under a safety bar. Finally, the report includes a quantitative study of the effectiveness of a flyback screen in stopping/slowing down fly-back events.

2.Methodology

2.1. Experimental Setup

The study was conducted at the AMC Thermodynamics Laboratory Workshop using the bespoke flyback simulation test setup developed for a previous round of flyback tests [1]. The flyback simulation setup was designed to provide constant tension to all tested fishing line setups.

Three configurations were investigated:

A **standard** (i.e. no protection) configuration where the monofilament line was stretched directly from the trigger mechanism to the tensioning frame pulley. This configuration is illustrated in Figure 1.

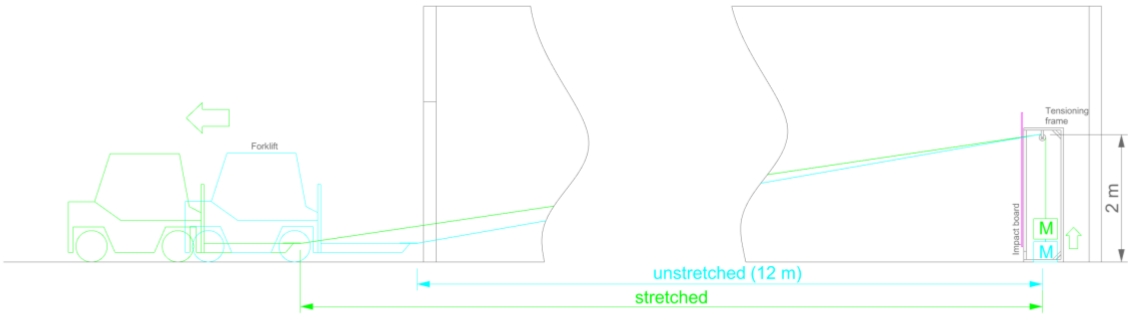


Figure 1 Experimental setup diagram (standard)

A **safety bar** configuration where the monofilament line was stretched from the trigger mechanism to the tensioning frame pulley whilst guiding it under a 62mm outer diameter round bar located 0.8m ahead and below the tensioning frame pulley. This configuration is illustrated in Figure 2.

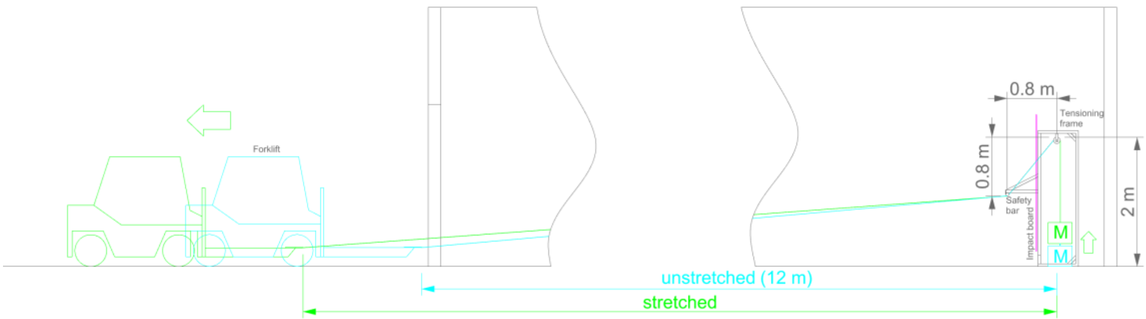


Figure 2 Experimental setup diagram (safety bar)

A **flyback screen** configuration where the monofilament line was stretched directly from the trigger mechanism to the tensioning frame pulley whilst passing through an orifice cut into a 350gsm Spider-MeshTM PVC screen located 0.9m ahead of the tensioning frame pulley. This configuration is illustrated in Figure 3. Two conditions; loose and tight were studied. In the loose condition the bottom edge of the screen was left loose. In the tight condition a metal rod was attached to the bottom edge of the screen to generate tension. Both conditions are shown in Figure 4.

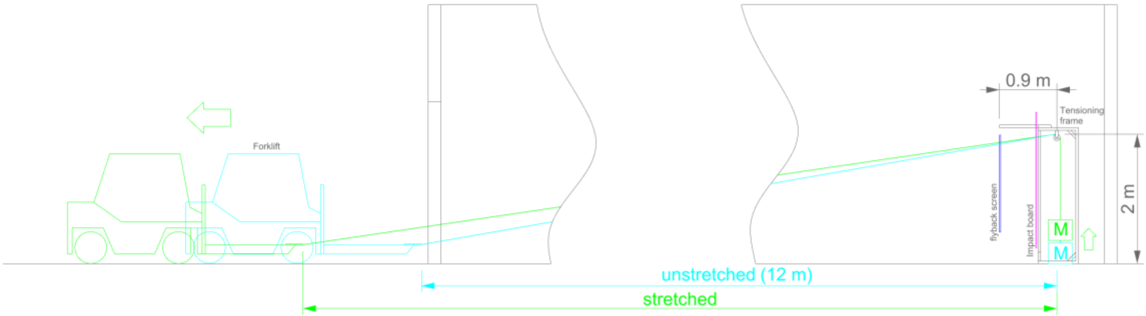


Figure 3 Experimental setup diagram (flyback screen)

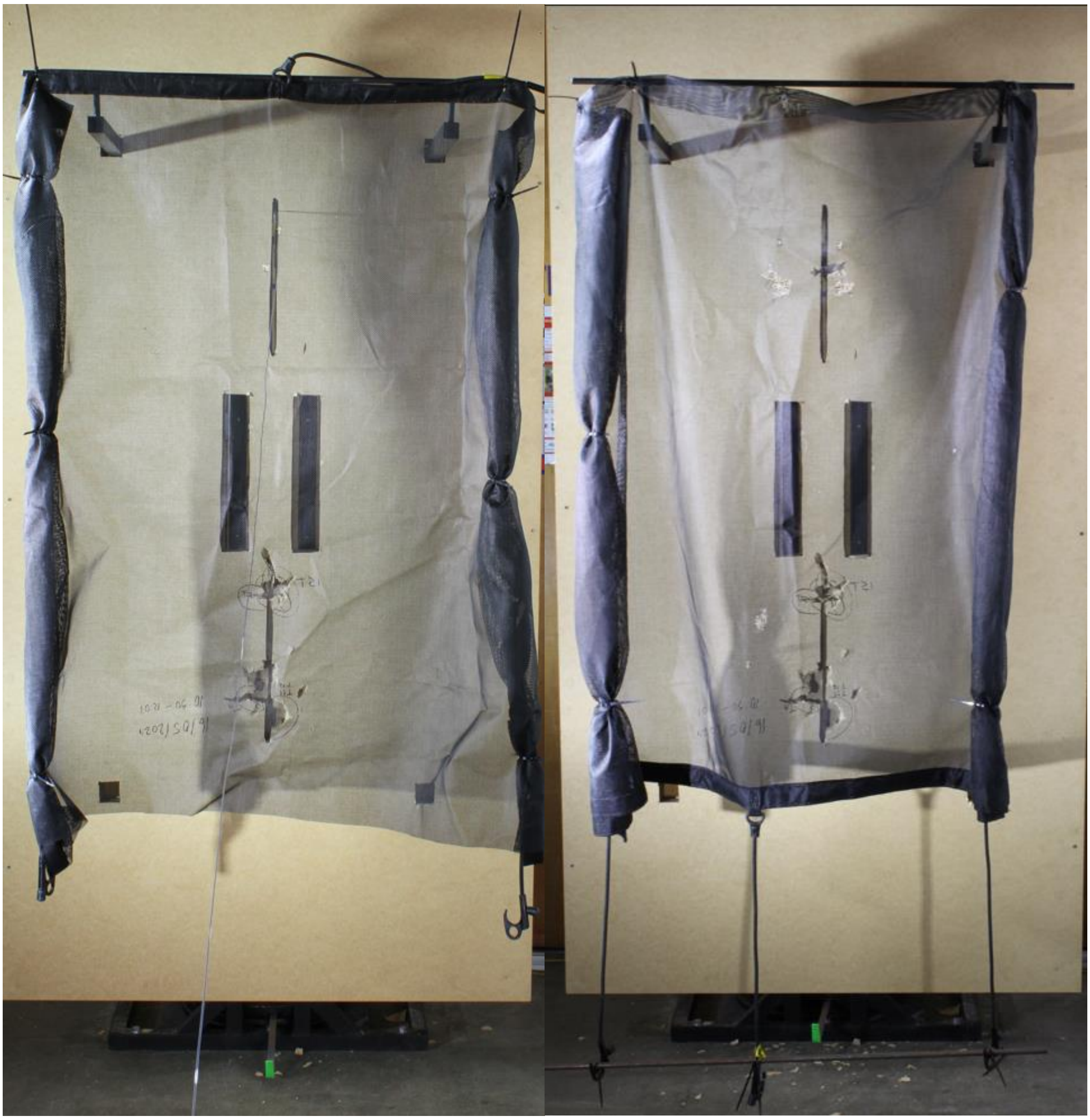


Figure 4 Flyback screen – loose (left) and tight (right) conditions

As in the previous test campaign [1], the hook end of each monofilament longline branch arrangement, described in Section 2.2, was connected to trigger mechanism located at the tip of a forklift tine positioned outside the workshop space.
Due to intermittent problems with the original trigger release system (quick-release snap shackle) a new bespoke lever action trigger system, presented in Figure 5, was adopted for the present set of tests. The trigger mechanism used a cable-actuated pivoting lever to release the hook when the desired tension was achieved.

Figure 5 New lever action trigger system.

The opposite end of the monofilament line was attached to a 76.64kg mass (M) through a pulley located atop of the tensioning frame. Tension on the line was achieved by reversing the forklift until the mass lifted off the ground as shown in the diagram below.
An impact MDF board was attached to the front of the tensioning frame to slow down the projectiles. A slit was machined in the board to allow the wiring of the monofilament line through the tensioning frame pulley. The point at which the monofilament line passed through the impact board was set as the datum for all position calculations reported in Section 3 of this report.

2.2. Tested Branchline Arrangements

All branchlines were 14m long and constructed of 1.8mm clear Fujiyama nylon monofilament except for the standard gear (45g swivel) – see below for details. The arrangements to test the different branchline weighting designs were:

Standard gear (60g swivel)

The branchline was comprised of two sections of monofilament line with the upper section representing the hauling end being 10.5m and the lower section the end of the branchline being 3.5m from the hook. The two sections were joined by crimping the line through the fixed 60g weight swivel, shown in Figure 6, using 2 x E-size alloy single crimps. The monofilament loops were covered by anti-chafe soft nylon sleeving to minimise breakage around these joints. The hook attacked to the end of the branchline was a 13/0 forged Stainless Steel (4.2mm) offset circle hook with ring. The small loop used as the attachment point for the test weight was swaged using 2 crimps. A stainless leaded fixed weight swivel is set 3.5m from the hook.

Figure 6 Standard gear (60g swivel)

Standard gear (45g swivel)

This arrangement mimicked the one used for the Standard gear (60g swivel) configuration but was constructed using a thicker, 2.1mm diameter monofilament and by setting a 45g stainless leaded fixed weight swivel, shown in Figure 7, 1m from hook to replicate the standard gear configuration from US / NZ longline fisheries.

Figure 7 Standard gear (45g swivel)

Sliding Safety Lead (98g SSL)

The GloLead MkII Short Sliding Safety Lead, shown in Figure 8, was set 4m from the hook using hand tensioning. The monofilament branchline was threaded directly through the sliding lead. The hook attacked to the end of the branchline was a 13/0 forged Stainless Steel (4.2mm) offset circle hook with ring. The small loop used as the attachment point for the test weight was swaged using 2 crimps.

Figure 8 GloLead MkII Short Sliding Safety Lead (98g SSL)

Procella MkII Weighted Hook (62g weighted hook)

The Procella MkII weighted hook, shown in Figure 9, consists of a weight welded to a "cetacean friendly" (4.5mm maximum diameter hook gauge) 16/0 circle hook. The Procella weighted hook was attached directly to the end of the 14m branchline using a swage and anti-chafe connection to ring on hook. The small loop used as the attachment point to the test weight was swaged using 2 crimps.

Figure 9 Procella MkII Weighted Hook (62g weighted hook)

Yamazaki leader

The Yamazaki leader is a two piece "bottom section" of branchline totalling 3.5m in length. This consists of the Yamazaki system (1.2m no stretch coated wire with a fixed 30g lead and "running" 20g lead), shown in Figure 10, linked to a 2.3m mono section to the 13/0 ringed hook.

Figure 10 Yamazaki leader

2.3. High-speed Camera Setup

Two Photron FASTCAM S-AZ 2100K cameras were utilised to capture high speed images of the flyback impacts against the MDF impact board.
The cameras were mounted on an 80/20 aluminium extrusion spreader beam fixed atop a heavy-duty metrology tripod. The tripod was positioned behind protective polycarbonate screens shooting approximately perpendicular to the flyback direction as shown in Figure 11. An 841mm spacing between the cameras was chosen to achieve the recommended horizontal shooting angle difference between the two cameras of approximately 15 degrees at the expected point of impact.

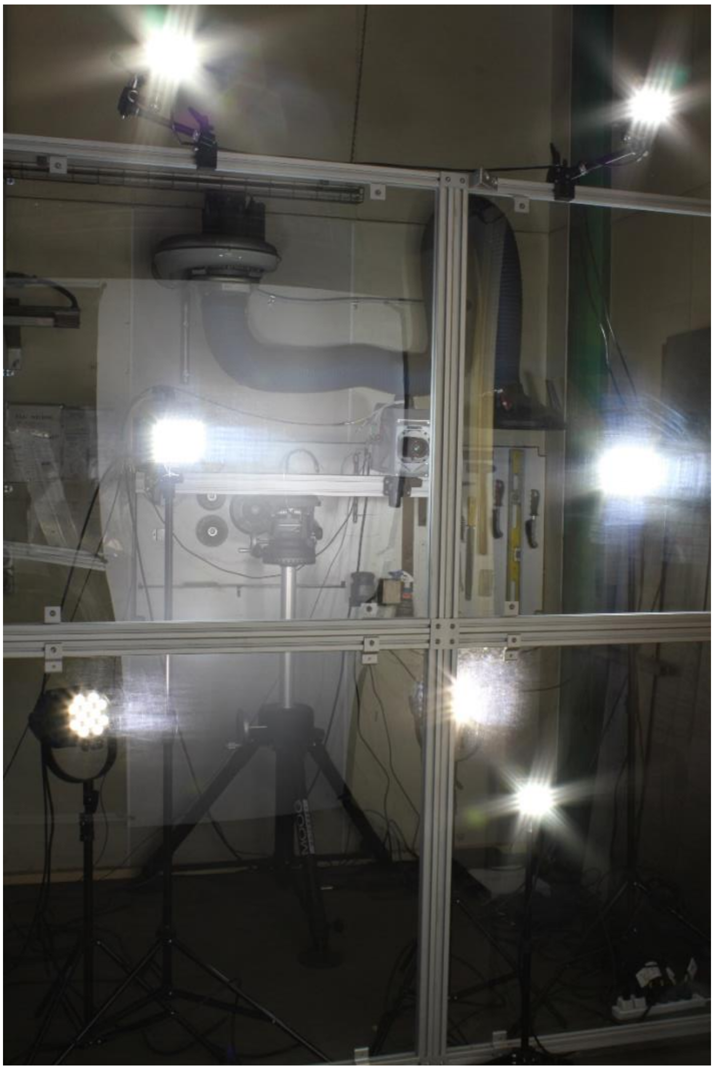


Figure 11 High-Speed camera setup

The target area was illuminated using four GSVitec MULTI LED QX LED lights, two GSVitec MULTI LED MX LED lights and two NILA VARSA high power LED lights. Both the QX and MX GSVItec lights were connected through a MULTILED GX8 controller.

2.4. DIC Calibration

The cameras were calibrated using a laser etched aluminium calibration target with 56mm dot spacing as shown in Figure 12 using a 2nd order radial calibration using 47 image pairs.

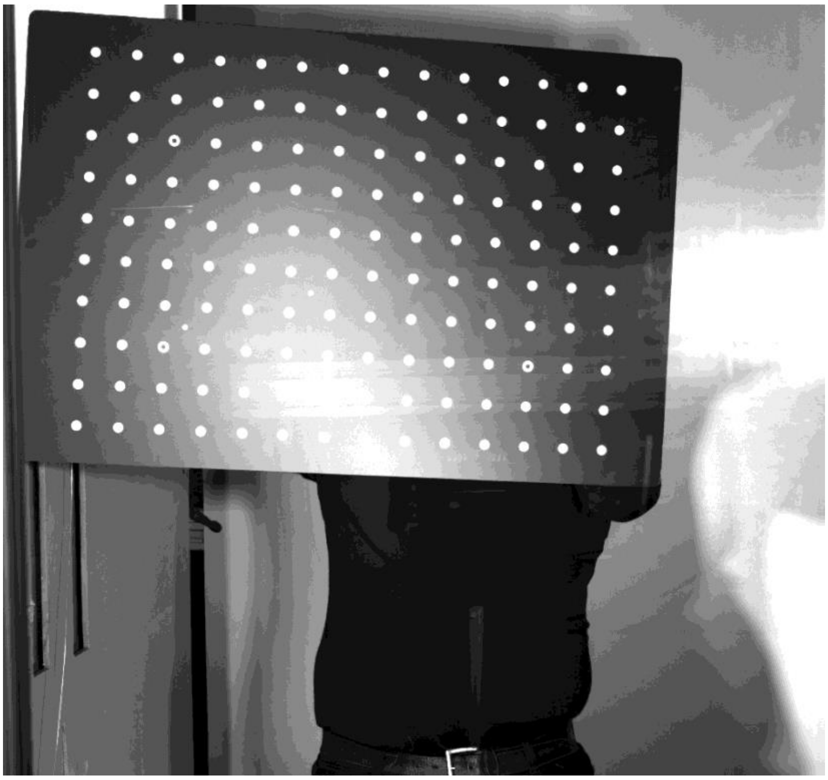


Figure 12: Calibration of the cameras was performed using a calibration target.

The camera height was set to capture the impact for all set-ups as shown in Figure 13. Image pairs were captured at a frame rate of 20,000 fps with a resolution of 1024 x 1024.

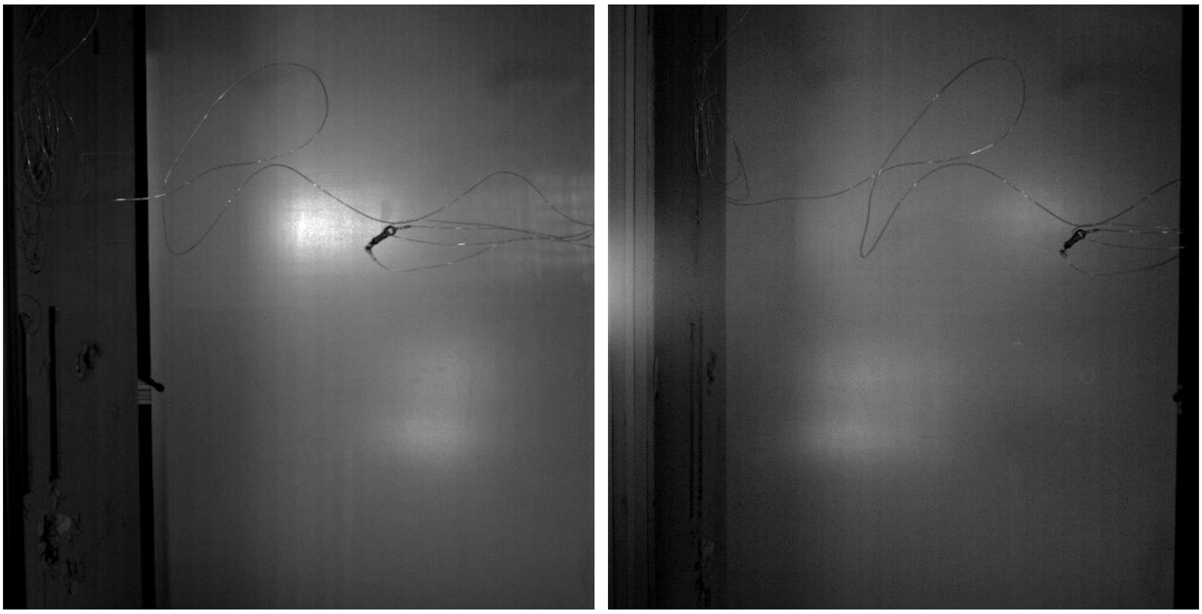


Figure 13: Image pairs from tests.

DIC Image Processing

The images were post processed using VIC-3D Digital Image Correlation software. Markers were manually identified to determine the position and velocity of the key object identified in each line arrangement. Two markers were tracked on each of the identified arrangement to account for rotation as shown in Figure 14. The position of the markers was determined in three dimensions and then corrected according to the datum.
The velocity was calculated using:

$$V_{x,y,z} = \frac{P_{1(x,y,z)} - P_{0(x,y,z)}}{t_1 - t_0}$$

Where V is the velocity in mm/s, P is the position in mm and t is the time in seconds. To account for rotation, the reported velocity of each run is the average of the two identified points. It was assumed there was negligible change in velocity over the distance measured. The impact location was calculated by projecting the velocity until it reached the MDF impact board.

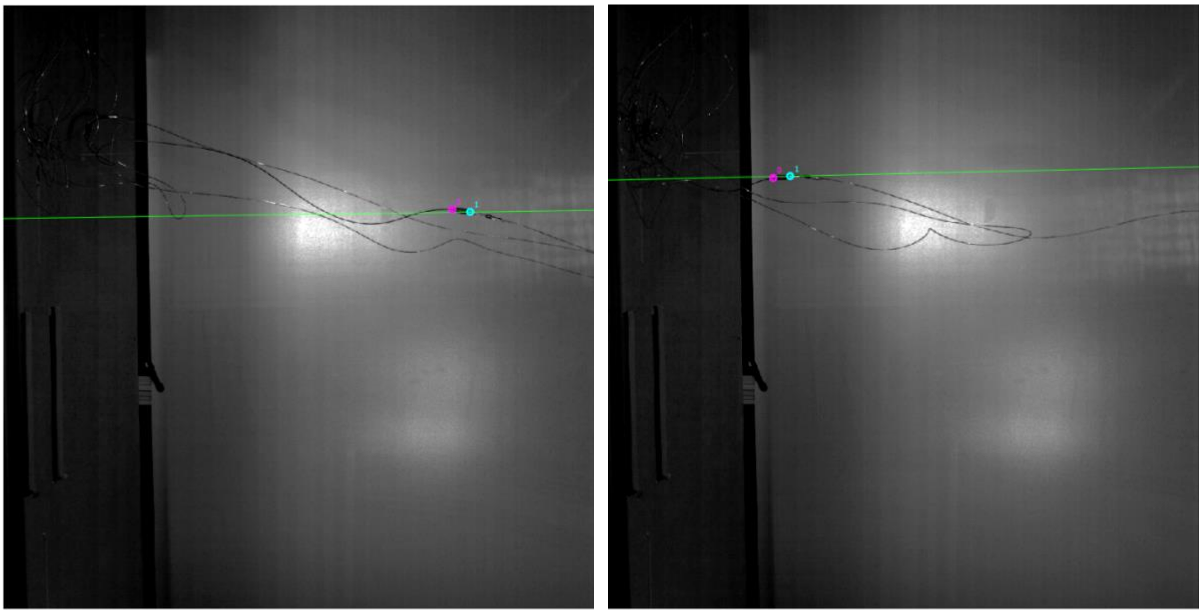


Figure 14: Images demonstrating the tracking of the swivel[2]

[2] Note the tracking of two points (in magenta and cyan) to account for changes in the orientation of the swivel during its flight.

3.Results

A total of 35 runs were completed, 20 in the standard configuration, 5 with the safety bar and 10 with the screen. A summary of the results of the testing is presented in Table 1 for the swivel/weight and Table 2 for the hook. For each result, the following parameters are provided:

Run – test number

Branchline arrangement –98g SSL, 45g swivel, 62g weighted hook, Yamazaki leader or 60g swivel

Object tracked – Weight/Swivel (W) or Hook (H)

Protection System – nil, OD62 Flyback Bar, Screen loose or Screen tight

Velocity – measured velocity

In mm/s

In km/hr

Impact location – position of the impact at the MDF impact board relative to the datum

horizontal location in mm

vertical location in mm

Notes – any other relevant information

Where the impact occurred outside of the field of view of the camera, no velocity or impact position data has been provided. Additional notes for these runs have been provided where possible. A graphical representation of the swivel impact locations are provided in Figure 16 to Figure 21.

Tests performed with a protective screen typically did not suffer from punch through on the initial hit. However repeated hits at the same location resulted in damage to the netting and punch through events. These are noted in the Notes section.

Figure 15: Demonstration of a no punch through (left) and punch through, highlighted in red, (right) of the protective screen

Finally, Figure 22 and Figure 23 present the average velocity and 95% confidence intervals for each setup in mm/s and km/hr respectively.

Table 1: Summary of testing results for weight/swivel

						Impact Location		
Run	Branchline Arrangement	Object tracked	Protection system	Velocity [mm/s]	Velocity [km/hr]	Vertical Position [mm]	Horizontal Position [mm]	Notes
01	98g SSL	W	-	18109	65	-787	94	
02	98g SSL	W	-	-	-	-	-	No swivel in frame
03	98g SSL	W	-	28915	104	-200	-22	
04	98g SSL	W	-	32916	118	-230	14	
05	98g SSL	W	-	31089	112	-346	0	
06	45g swivel	W	-	58024	209	-72	-31	
07	45g swivel	W	-	56473	203	-178	28	
08	45g swivel	W	-	59908	216	-131	40	
09	45g swivel	W	-	57157	206	-107	54	
10	45g swivel	W	-	55573	200	-40	-76	
11	62g weighted hook	W	-	67216	242	20	-2	
12	62g weighted hook	W	-	68623	247	11	14	
13	62g weighted hook	W	-	68919	248	-30	52	
14	62g weighted hook	W	-	67509	243	-10	71	
15	62g weighted hook	W	-	69196	249	-86	48	
16	Yamazaki leader	W	-	55419	200	-52	50	Swivel one
16	Yamazaki leader	W	-	61340	221	-83	20	Swivel two
17	Yamazaki leader	W	-	56162	202	16	-39	Swivel one
17	Yamazaki leader	W	-	59606	215	-61	-77	Swivel two
18	Yamazaki leader	W	-	56860	205	-67	-21	Swivel one
18	Yamazaki leader	W	-	60804	219	-87	-77	Swivel two
19	Yamazaki leader	W	-	56428	203	-14	-37	Swivel one
19	Yamazaki leader	W	-	62075	223	-87	-65	Swivel two
20	Yamazaki leader	W	-	57858	208	-41	-140	Swivel one

						Impact Location		
Run	Branchline Arrangement	Object tracked	Protection system	Velocity [mm/s]	Velocity [km/hr]	Vertical Position [mm]	Horizontal Position [mm]	Notes
20	Yamazaki leader	W	-	62238	224	-79	-54	Swivel two
21	60g swivel	W	OD62 flyback	65265	235	-772	6	
22	60g swivel	W	OD62 flyback	65692	236	-783	-16	
23	60g swivel	W	OD62 flyback	64732	233	-768	73	
24	60g swivel	W	OD62 flyback	64771	233	-769	27	
25	60g swivel	W	OD62 flyback	66106	238	-761	48	
26	60g swivel	W	Screen loose	62448	225	-1	-12	No punch through
27	60g swivel	W	Screen loose	61475	221	-6	9	No punch through
28	60g swivel	W	Screen loose	62054	223	-6	-5	No punch through
29	60g swivel	W	Screen loose	63644	229	-14	0	No punch through
30	60g swivel	W	Screen loose	64528	232	-21	-18	Punch through
31	60g swivel	W	Screen tight	62074	223	-31	37	No punch through
32	60g swivel	W	Screen tight	60999	220	22	4	No punch through
33	60g swivel	W	Screen tight	64650	233	-19	11	Punch through
34	60g swivel	W	Screen tight	62105	224	15	-6	Punch through
35	60g swivel	W	Screen tight	61922	223	-24	0	Punch through

Table 2: Summary of testing results for hook only

						Impact Location		
Run	Branchline Arrangement	Hook (H) or Weight/Swivel (W)	Protection system	Velocity [mm/s]	Velocity [km/hr]	Vertical Position [mm]	Horizontal Position [mm]	Notes
01	98g SSL	H	-	-	-	-	-	No hook in frame
02	98g SSL	H	-	-	-	-	-	No hook in frame
03	98g SSL	H	-	-	-	-	-	No hook in frame
04	98g SSL	H	-	-	-	-	-	No hook in frame
05	98g SSL	H	-	-	-	-	-	No hook in frame
06	45g swivel	H	-	-	-	-	-	No hook in frame
07	45g swivel	H	-	53198	192	-111	118	
08	45g swivel	H	-	57967	209	52	23	
09	45g swivel	H	-	54804	197	-5	84	
10	45g swivel	H	-	62703	226	-81	-25	
11	62g weighted hook	H	-	-	-	-	-	No hook in frame
12	62g weighted hook	H	-	-	-	-	-	No hook in frame
13	62g weighted hook	H	-	-	-	-	-	No hook in frame
14	62g weighted hook	H	-	-	-	-	-	No hook in frame
15	62g weighted hook	H	-	-	-	-	-	No hook in frame
16	Yamazaki leader	H	-	54476	196	135	-38	
17	Yamazaki leader	H	-	56858	205	132	-213	
18	Yamazaki leader	H	-	55026	198	45	-95	
19	Yamazaki leader	H	-	59436	214	-11	-27	
20	Yamazaki leader	H	-	58120	209	-106	-41	
21	60g swivel	H	OD62 flyback	67776	244	-420	22	
22	60g swivel	H	OD62 flyback	64083	231	-418	208	
23	60g swivel	H	OD62 flyback	63533	229	-454	-14	
24	60g swivel	H	OD62 flyback	65654	236	-236	-226	
25	60g swivel	H	OD62 flyback	63033	227	-217	115	

						Impact Location		
Run	Branchline Arrangement	Hook (H) or Weight/Swivel (W)	Protection system	Velocity [mm/s]	Velocity [km/hr]	Vertical Position [mm]	Horizontal Position [mm]	Notes
26	60g swivel	H	Screen loose	-	-	-	-	No hook in frame
27	60g swivel	H	Screen loose	-	-	-	-	No hook in frame
28	60g swivel	H	Screen loose	-	-	-	-	No hook in frame
29	60g swivel	H	Screen loose	59746	215	309	-20	No punch through
30	60g swivel	H	Screen loose	59165	213	-265	-55	No punch through
31	60g swivel	H	Screen tight	-	-	-	-	No hook in frame
32	60g swivel	H	Screen tight	-	-	-	-	No hook in frame
33	60g swivel	H	Screen tight	-	-	-	-	No hook in frame
34	60g swivel	H	Screen tight	-	-	-	-	No hook in frame
35	60g swivel	H	Screen tight	62605	225	-88	162	No punch through

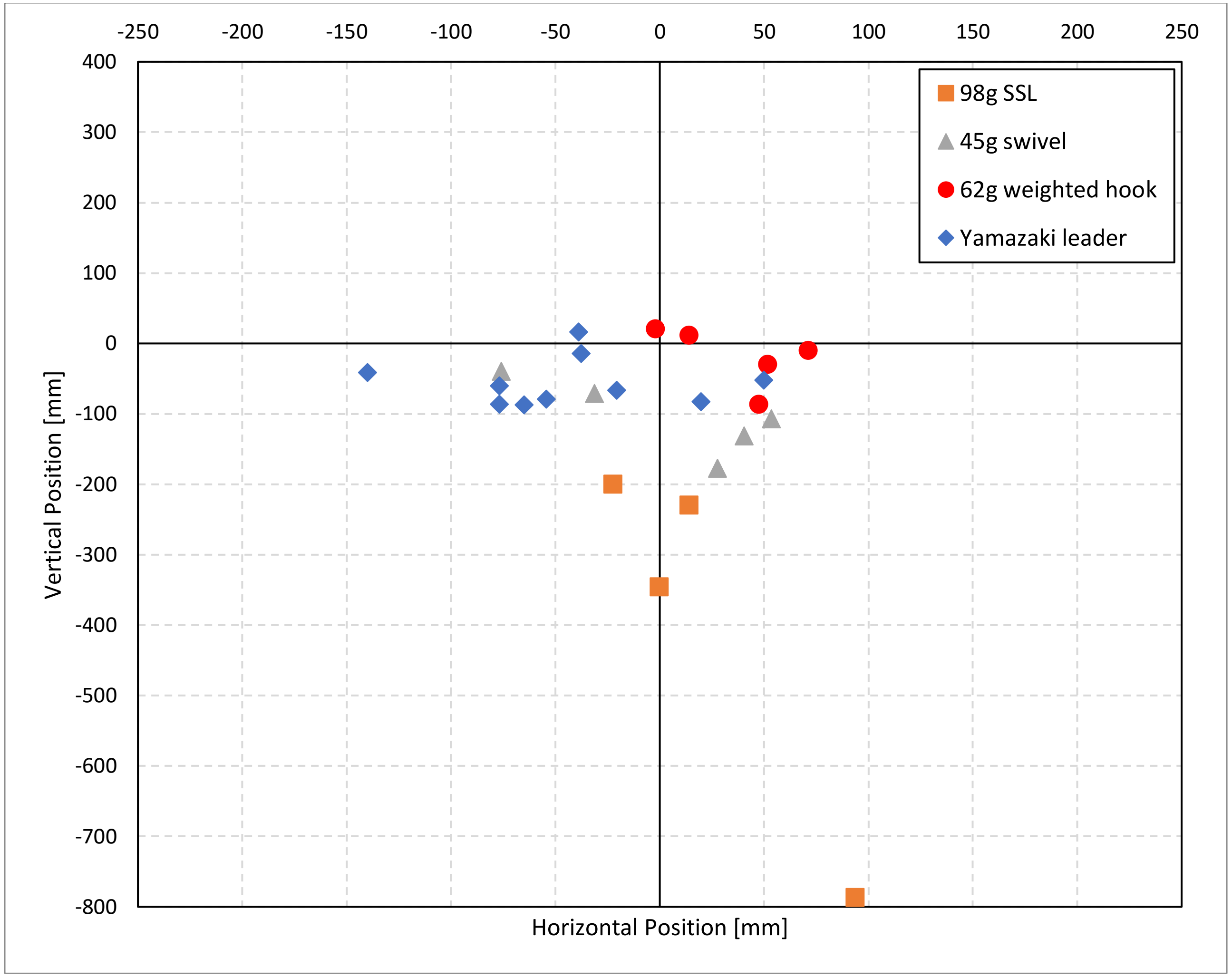


Figure 16: Impact position for all tests except OD62 Flyback Bar and Flyback Screen.

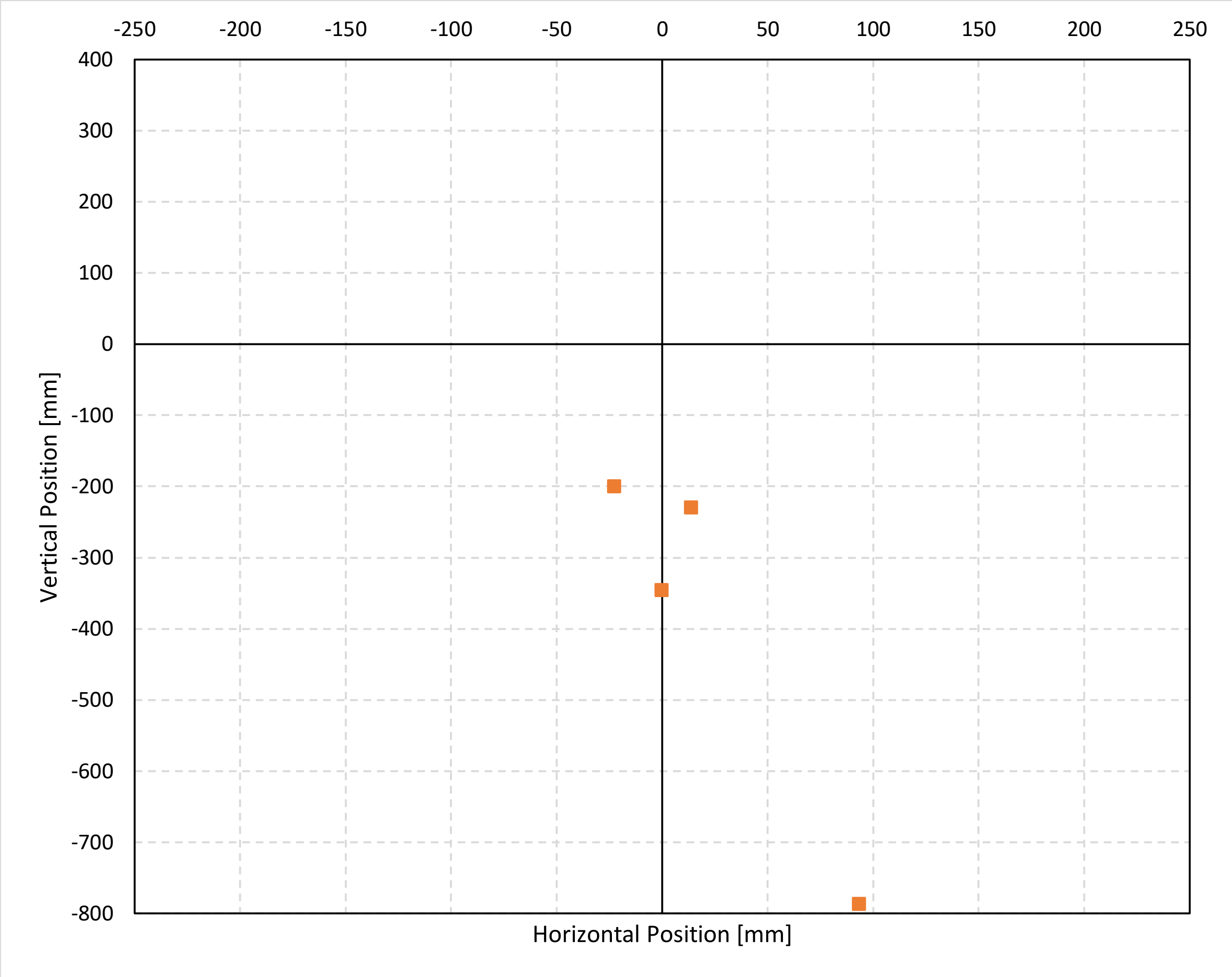


Figure 17: Impact position for the 98g SSL.

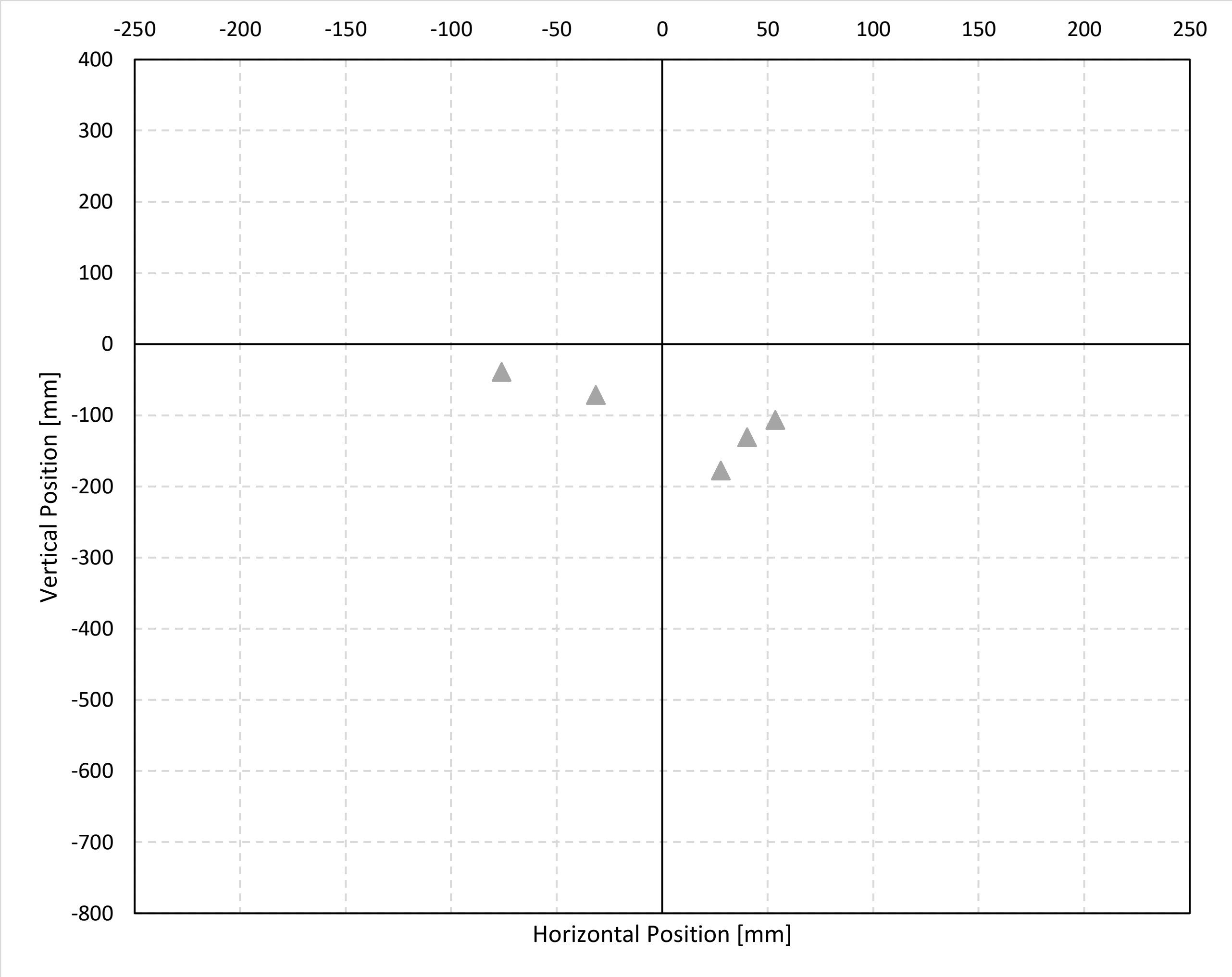


Figure 18: Impact position for the 60g swivel.

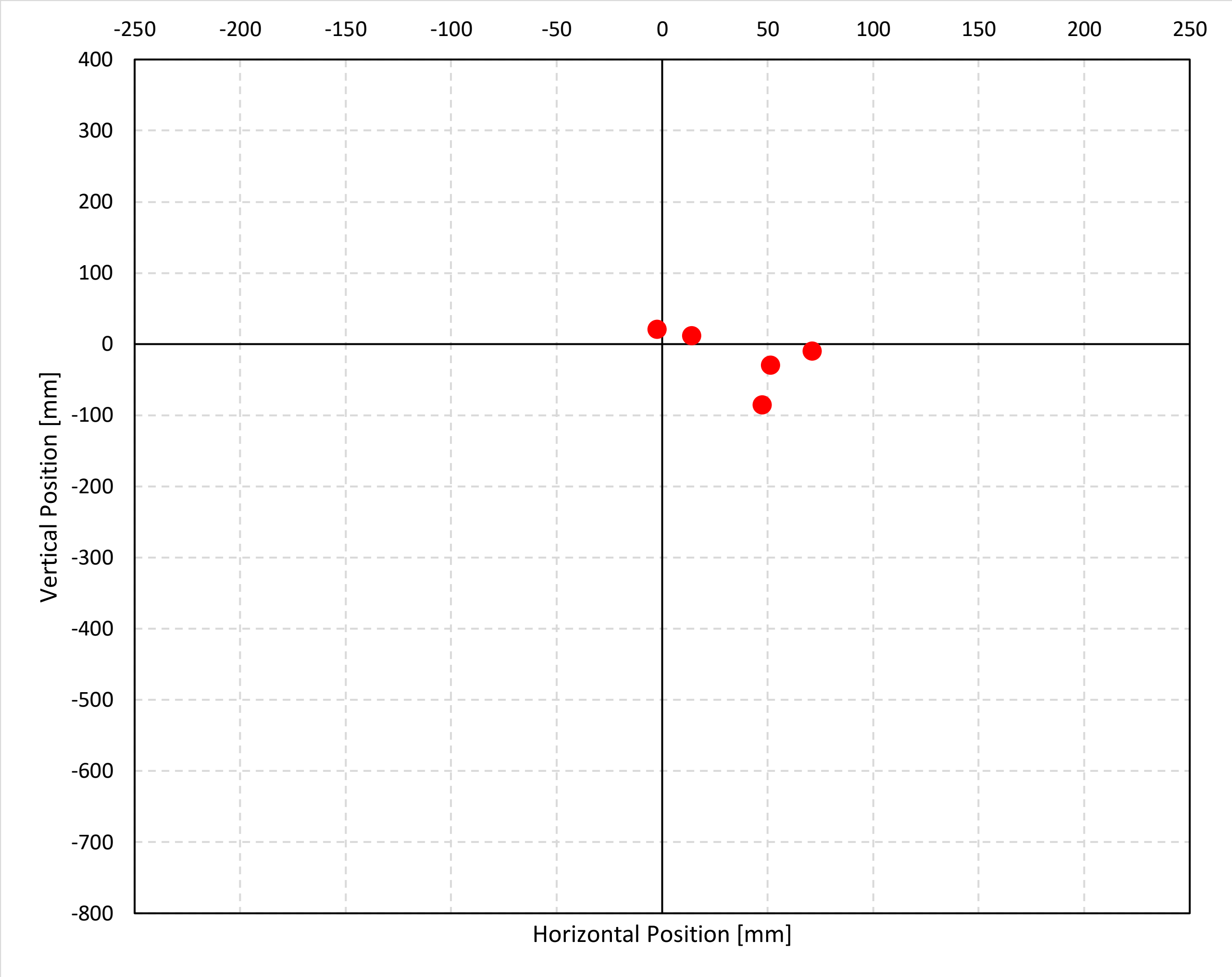


Figure 19: Impact position for 62g weighted hook.

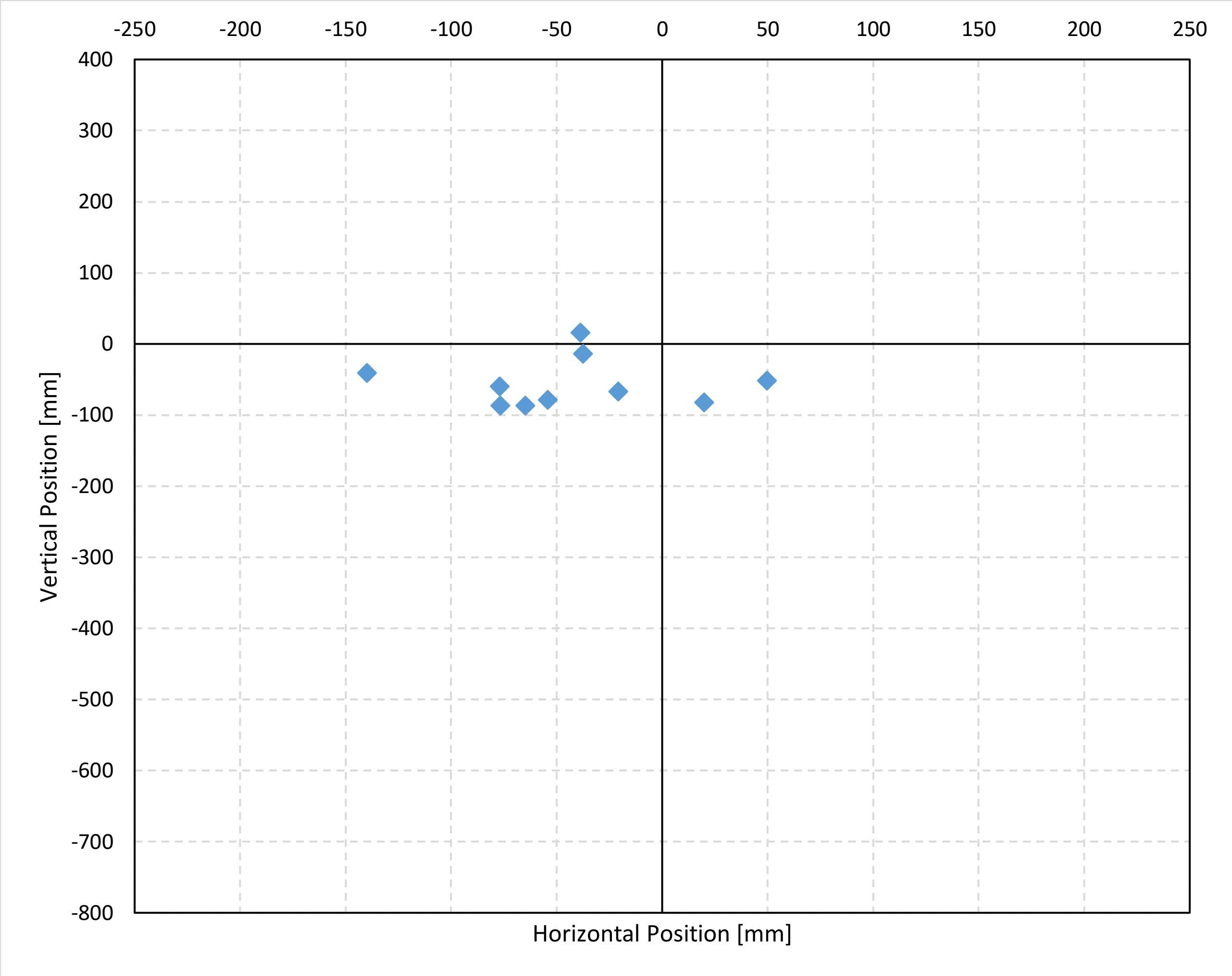


Figure 20: Impact position for Yamazaki Setup.

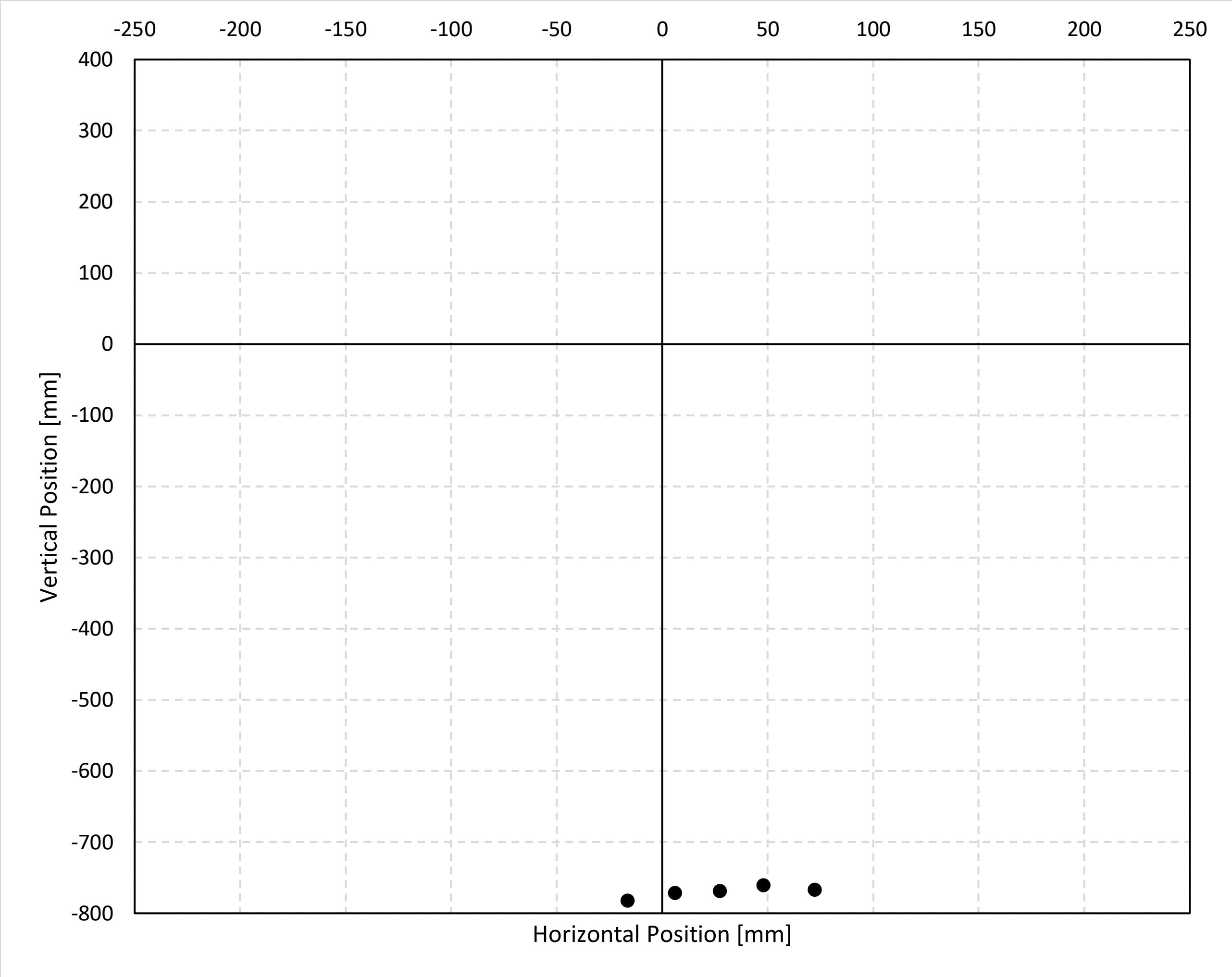


Figure 21: Impact position for OD62 Flyback Bar with the 60g swivel.

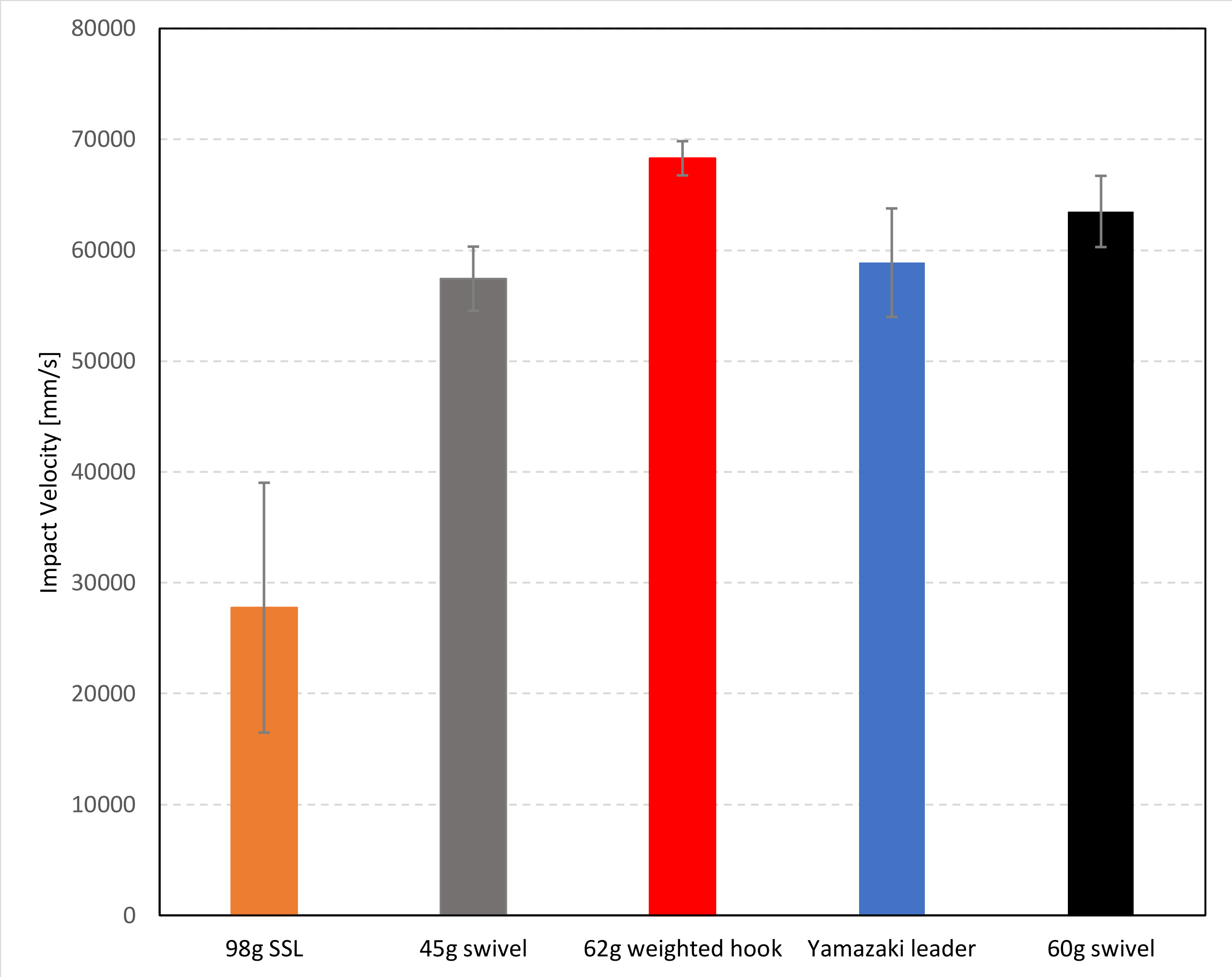


Figure 22: Average velocity and 95% confidence intervals for each setup in mm/s3

[3] Note: Velocity is not the only indicator of lethality

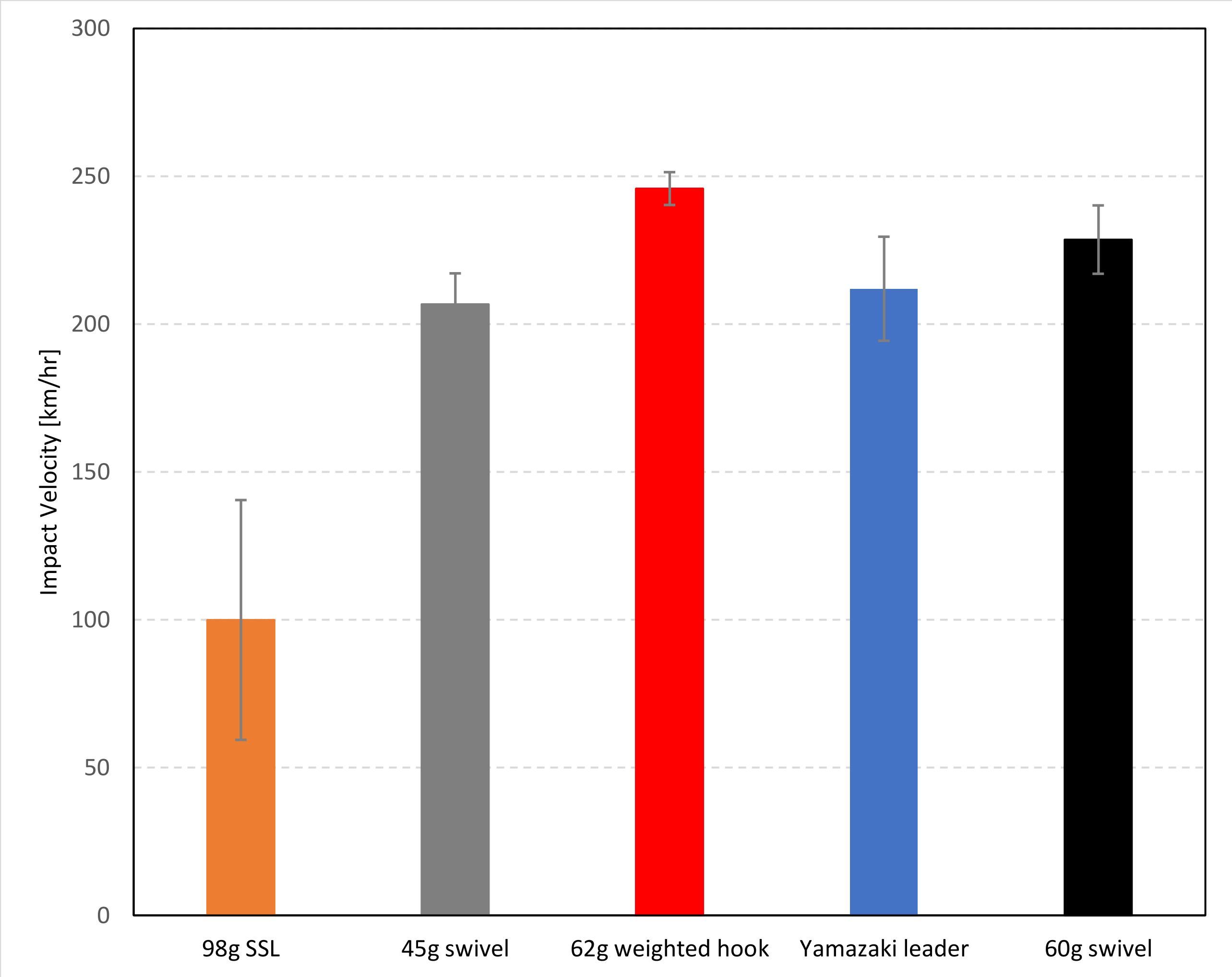


Figure 23: Average velocity and 95% confidence intervals for each setup in km/hr4

[4] Note: Velocity is not the only indicator of lethality

4.Appendices

This report includes the following digital appendices:
High-speed video of each test
Excel file containing a summary of results.

5.References

1. Mitchell Ferguson, T., R. Ojeda, and N. Rawlinson, Fishing Line Flyback Simulation Project. 2023, Australian Maritime College: Launceston, Tasmania. p. 19.

Appendix 8 - Fishtank presentation – final

Improving the effectiveness, efficiency and safety of mitigation tools for protected species interactions in the Eastern Tuna and Billfish Fishery

Fishtank presentation – Seafood Directions 2024

This file can be viewed at FRDC Project page - https://www.frdc.com.au/project/2020-041.

Appendix 9 - Supplementary project images

Supplementary project images supporting method development, results, and extension

Supplementary project images

The following images support report methods, results and extension aspects of the Project 2020-041.

Figure 1 Procella original and improved version (left) and prototype weighted hooks (right) showing decreased hook gape due to positioning of weight. Procella variants were tested in flyback simulations.

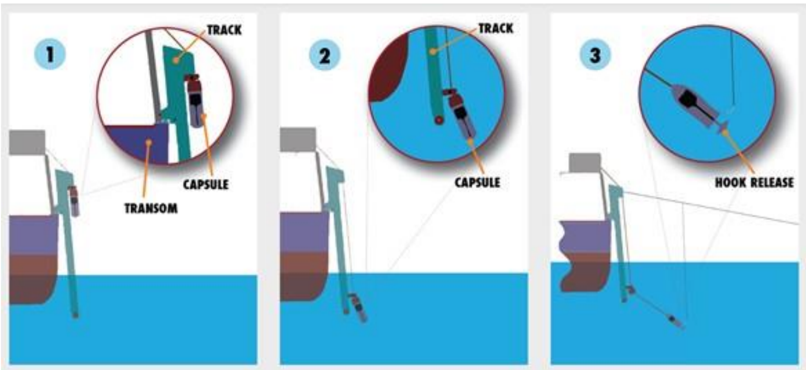


Figure 2 Concept schematic drawings of the Underwater bait setting device demonstrating how the system works

Source: Skadia https://skadiatech.com/discover/

Figure 3 Concept magnesium banding connecting the hook to weighted swivel to offer hook protection and improve sink rate.

This concept was not pursued for testing due to the handling and engineering challenges of connecting the magnesium band. For accelared galavanic corrosion would require the magnesium band to be a single strand and be in direct contact with the stainless steel hook.

Figure 4 Concept Smart Tuna Hook and infographic on their use.

Further information can be found here - https://www.cleancatchuk.com/mitigation/smart-tuna-hook/

Figure 5 Additional images of Tori lines tested in the project - Tori line A (L panel) and Tori line B (R panel).

The second tori line (tori line B) was constructed using materials familiar to longline fishers, but not commonly used in tori line construction. These materials included Sekiyama braid for the backbone and trailing line, stiff pallet strapping in two high-visibility colours, and crane swivels to provide fixed attachment points for the streamers.

Figure 6 Tori line A with paired streamers

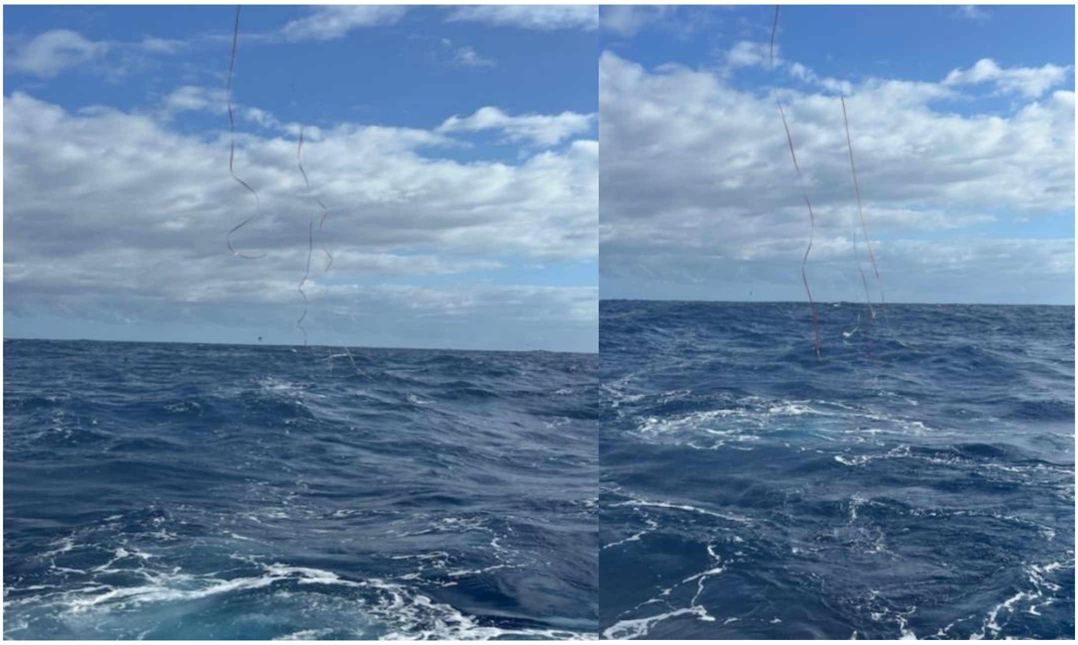


Figure 7 Tori line B showing single stand pallet strapping demonstrating greater movement and unpredictability compared with paired streamers.

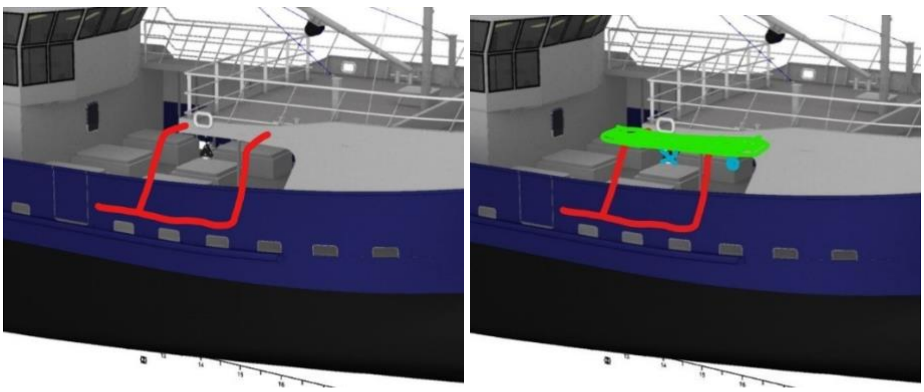


Figure 8 Mock up designs for Mira S during the development of the flyback bar concept

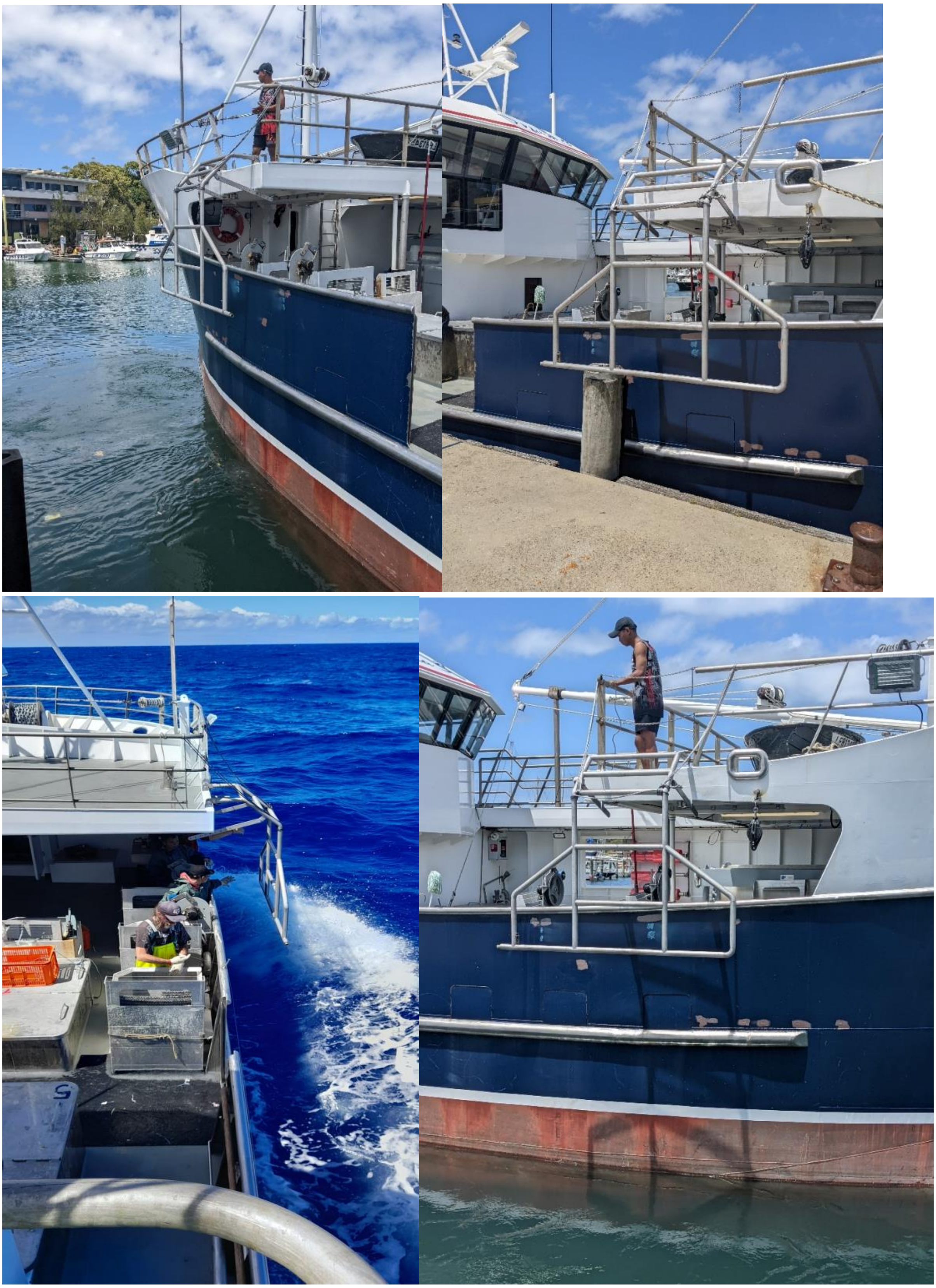


Figure 9 Mira S safety bar deployed in port and in use at sea.

Figure 10 Preliminary design of the flyback bar concept for FV Scorpion and planning activities onboard.

Figure 11 Images of the construction of the flyback bar on the FV Scorpion.

Figure 12 Images of the flyback bar simulating system at the Australian Maritime College, Launceston, Tasmania.

Figure 13 Close up of the testing of the diameter of the flyback bar and the damage caused from simulated flyback events.

Figure 14 Flyback simulation environment showing technology and research ‘Myth Busters’ team from AMC Search.

Figure 15 Results of a flyback striking taut “Spidermesh” screen (L panel) and a loose sceen (R panel).

The screen was most effective when hung “loose” in the flyback simulation jig as the weight was captured by the screen. However, repeated flyback events stress the screen.

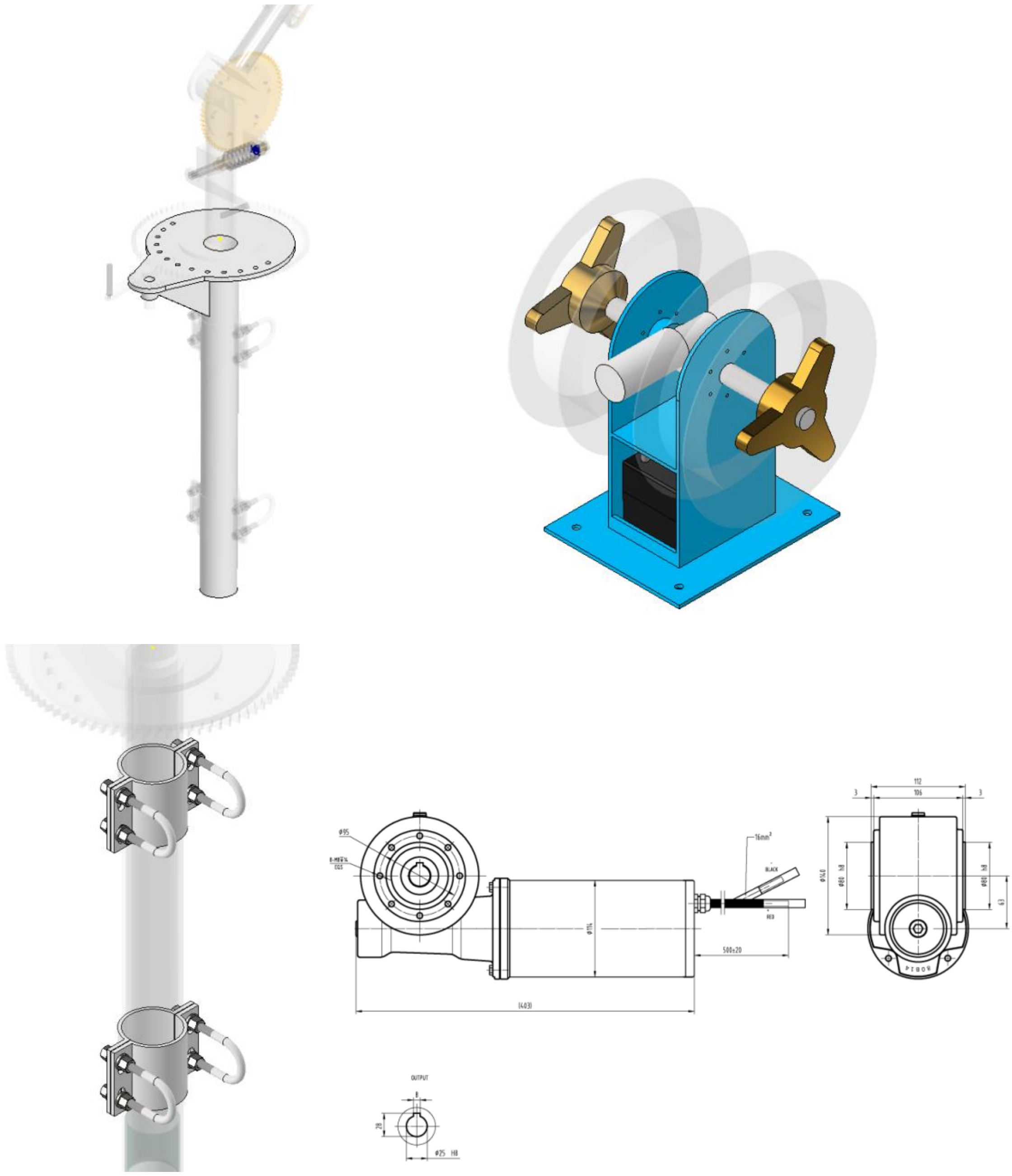


Figure 16 Additional engineering design components created by AMC Search using CAD software.

Key elements of the design which will benefit industry include:

- The longevity of the system is supported by the materials selected, including 316-grade stainless steel for the tori pole and gearing system that drives movement, and silicone bronze for the worm gear and cone clutch. Silicone bronze was chosen for its self-lubricating properties and high resistance to corrosion.
- The design proposes the use of a 1250 W electric motor and gearbox sourced from a winch-anchor application. A Savwinch-branded motor was recommended, as these units are readily available for recreational boating, cost-effective, have a long service life, and are well suited to this application given the relatively low power required to retrieve the tori line.

- Automatic retrieval via the cassette drive system helps maintain the tori line in good condition and removes the need for manual handling. This reduces the risk of repetitive strain injuries and minimises the likelihood of injury from free-spinning components.
- The forces required to move the pole under load necessitated careful consideration of operator safety. This risk is mitigated through the use of a self-locking worm gear, which prevents back-driving of the handle and eliminates the potential for operator injury during use.
- The estimated cost of materials for fabrication of the complete system is approximately $7,500. Due to the modular design, the adaptable tori pole componentry alone can be sourced for as little as $3,500, making the system highly accessible to industry. This compares favourably with deck-mounted standalone tori poles, which require permanent deck penetrations, installation of stays, and are difficult and costly to relocate.
- A simple flag-pole style pulley system has been incorporated to allow rapid change-out of tori lines. An additional attachment point is included to enable connection of a recovery line, safeguarding against loss of the tori line if it becomes entangled with fishing gear.

Figure 17 Project Manager Phil Ravanello and AMC Search researcher Dr Roberto Ojeda presented an interactive demonstration of the flyback simulation at Seafood Directions 2024 “FishTank” research forum.