Preliminary Integrated Bycatch Management Strategy and 2022 Workplan

for the

Tunago Fishery of the Pacific Ocean Tuna Longline (Thai Union) FIP

Version 1 (R1) – December 2021



Preliminary Integrated Bycatch Management Strategy and 2022 Workplan for the Tunago Fishery of the Pacific Ocean Tuna Longline (Thai Union) FIP

Prepared by:
Eric Gilman, Tom Evans, Iain Pollard, Craig Heberer, Francisco Leotte, Stephen Lo, Tony Taleo

Version 1 (R1) – December 2021

A report of Key Traceability Ltd., 1 Halpern House, Portsmouth, UK
England Registered Company 09730288

Prepared for the participants of the Pacific Ocean Tuna Longline Thai Union Fishery Improvement Project: Thai Union, Tunago Fishing Company, Vanuatu Fisheries Department, and The Nature Conservancy's Large-Scale Fisheries Program,

Support for this project was provided by Fondation Ensemble, the Pew Fellows Program in Marine Conservation at The Pew Charitable Trusts, The Nature Conservancy's Large-Scale Fisheries Program, The Safina Center Fellowship Program and Thai Union.

Contents

Summary

The participants of the Tunago component of the Pacific Ocean Tuna Longline Thai Union Fishery Improvement Project (FIP) implemented a decision support tool to develop an integrated bycatch management strategy and prepare a workplan for calendar year 2022 to begin implementation of the management strategy. This report describes the process that the FIP participants employed, the adopted integrated bycatch management strategy and workplan activities, milestone and schedule for 2022.

To develop their plan, the participants:

- Defined populations covered by the management strategy.
- Compiled current information on fishing practices and identified information gaps.
- Benchmarked the contemporary fisheries management framework, including monitoring, control, surveillance, enforcement and outcomes of enforcement actions; and identified information gaps.
- Adopted overarching goals, specific and objectives with measurable performance standards and milestones.
- Shortlisted bycatch mitigation methods that are relevant and feasible for implementation.
- Ranked candidate mitigation methods based on their ability to achieve objectives for bycatch mitigation and for acceptable costs, and feasibility of compliance monitoring.
- Conducted qualitative management strategy evaluation to compare how alternative management frameworks would meet objectives.

Following these planning steps, the FIP participants adopted a bycatch management strategy that met objectives for: (1) mitigating the catch and mortality of vulnerable bycatch species, (2) acceptable costs resulting from multispecies conflicts, (3) acceptable commercial viability (economic, practicality, safety) costs, and (4) improvements with the fisheries management system's monitoring, control, surveillance and enforcement components to enable achieving the bycatch objectives. A workplan for calendar year 2022 was developed to implement the management strategy.

The FIP participants' bycatch management plan includes regularly scheduled performance assessments that will inform adapting the management strategy and workplan as necessary. It is anticipated that this bycatch management strategy and workplan will be adapted in *ca*. late 2022 in order to account for more robust and comprehensive information obtained from a planned dockside inventory of the FIP fishing vessels and assessment of accumulated electronic monitoring data, and pending successful certification against the Marine Stewardship Council fisheries standard, to implement client activities to address conditions of certification.

1. INTRODUCTION

1.1. Integrated Management of Fisheries Bycatch

Incidental mortality or bycatch in fisheries is the largest threat to many populations of marine megafauna and an obstacle to sustainable seafood production. Fisheries targeting highly productive species can have profound impacts on co-occurring species that are also susceptible to capture that have delayed maturation, low fecundity and other life history traits that make them vulnerable to anthropogenic causes of mortality. Populations of these species can decline quickly and have limited recovery potential once depleted.

Some species of sharks, rays, marine turtles, marine mammals, seabirds and teleosts are threatened with extinction, in part, due to bycatch in pelagic longline and other marine capture fisheries. Numerous methods are now available that effectively mitigate bycatch of vulnerable species that are also economically viable, practical, safe and enable compliance monitoring, although there has been mixed progress in their uptake (Clarke et al. 2014; Gilman et al. 2014; Davidson et al. 2015; Hall et al. 2017). Furthermore, piecemeal bycatch management systems, with separate taxon-specific measures, can cause unintended multispecies conflicts (Gilman et al. 2019). Some methods that mitigate bycatch of one vulnerable species exacerbate the catch risk of others. This includes changes to hook shape, fishing depth and area-based management tools such as no-take marine protected areas.

This plan implements the integrated bycatch decision support tool of Gilman et al. (2021a) to supports stakeholders to design a bycatch management strategy, including to discover and adopt appropriate combinations of bycatch mitigation methods, to balance competing economic, social and ecological objectives related to managing vulnerable bycatch. The bycatch strategy enables the fishery stakeholders to strengthen the bycatch management system to meet their objectives to:

(1) Mitigate catch and mortality risks of vulnerable bycatch;
(2) Produce acceptable costs resulting from multispecies conflicts;
(3) Result in acceptable costs from reductions in practicality and crew safety;
(4) Achieve acceptable economic costs; and
(5) Enable feasible compliance monitoring of selected bycatch mitigation methods given both the effect of crew behavior on the performance of mitigation methods and the capacity of the fisheries management system.

1.2. Scope of the Bycatch Management Plan

This report describes the process that the FIP participants employed and the resulting adopted bycatch management strategy and workplan. This integrated bycatch management strategy and workplan is for the Tunago-owned vessels that are participating in the Pacific Ocean Tuna Longline Thai Union Fisheries Improvement Project (FIP). This plan updates a draft FIP bycatch management plan published in 2020 (Key Traceability, 2020a).

The scope of the bycatch strategy covers vulnerable species, including unwanted bycatch that are predominantly discarded and marketable species that are predominantly retained. We define unwanted bycatch as the catch that stakeholders of the Tunago-Thai Union fishery aim to avoid and minimize in order to address ecological and socioeconomic objectives. Because of the broad diversity in global fisheries, including in their markets, management frameworks and fisher practices, the definition of bycatch will vary broadly by individual fishery and over time. There is tremendous variability in bycatch definitions, including those adopted by different nations, in fishery-specific management plans and regulations, and in publications. For example, disparate bycatch definitions applied to tuna fisheries have included: species other than tunas (small scale tuna fisheries, Gillett 2011); dead discards (purse seine fisheries, Hall and Roman 2013); and species other than tuna and tuna-like species and billfishes (longline fisheries, Clarke et al. 2014). As a result, the Food and Agriculture Organization of the United Nations (FAO) has deemed it impossible to adopt a standard international definition of bycatch (FAO 2011).

Described in more detail in a subsequent section, the fishery stakeholders aim to transition from a FIP to a Marine Stewardship Council (MSC) certified fishery, and the primary goal underpinning this bycatch management strategy and plan is to have the fishery achieve a passing score when assessed against principle 2 of the MSC fisheries standard.

1.3. Tunago Fishery Component of Thai Union Pacific Tuna Longline FIP

The bycatch management strategy and workplan is for a fishery comprised of 10 distant-water pelagic longline vessels that fish across the Pacific Ocean. The vessels, which target primarily albacore tuna, are flagged to Vanuatu and owned by Tunago Fishery Co., a Taiwanese company. The vessels range in length between 46.5 and 53.5 m, have 30 crew and transship catch on the high seas (i.e., areas beyond national jurisdiction). The vessels land catch mainly in Suva, Fiji. This fishery is one component of the Thai Union Pacific Tuna Longline FIP (Key Traceability, 2021). The record for the Pacific Ocean Tuna – Longline Thai Union FIP is available at https://fisheryprogress.org/fip-profile/pacific-tuna-longline. FIP participants relevant to this bycatch strategy and plan are Thai Union (lead funder for the FIP), Key Traceability (FIP coordinator), Tunago Fishing Company, the Vanuatu Fisheries Department and The Nature Conservancy.

1.4. Summary of Ecological Risk Assessment Findings

An ecological risk assessment was prepared for the effects of the Tunago fishery of the Pacific Ocean Tuna Longline Thai Union FIP and posted on the FIP’s FisheryProgress.org record in January 2021 (Gilman et al., 2021b). Determining which populations are of highest ecological risk from fishing mortality guides management. Because no single approach is optimal across taxonomic groups, a multi-model ensemble of relative risk estimates for the fishery was obtained from two semi-quantitative Productivity-Susceptibility Analyses (PSAs) and from a quantitative approach that estimates instantaneous fishing mortality to compare to reference points of yield-per-recruit models.

Individual estimates were combined to produce a pooled mean relative risk rank order. The study also identified stocks below biological limits for which the contribution from this fishery to cumulative anthropogenic mortality may warrant intervention.

From the PSA, relative risks in descending order were for populations of albatrosses, cetaceans, mesopelagic sharks, rays, marine turtles, epipelagic sharks and teleosts. The fishery’s contribution to cumulative fishing mortality of western central north Pacific Ocean striped marlin warrants a more rigorous assessment to determine absolute risks. Figure 1 shows the relative risk rank order from the three individual risk assessments and an overall or pooled relative risk rank order, all using the same scale, and with populations/stocks ordered by the overall rank.

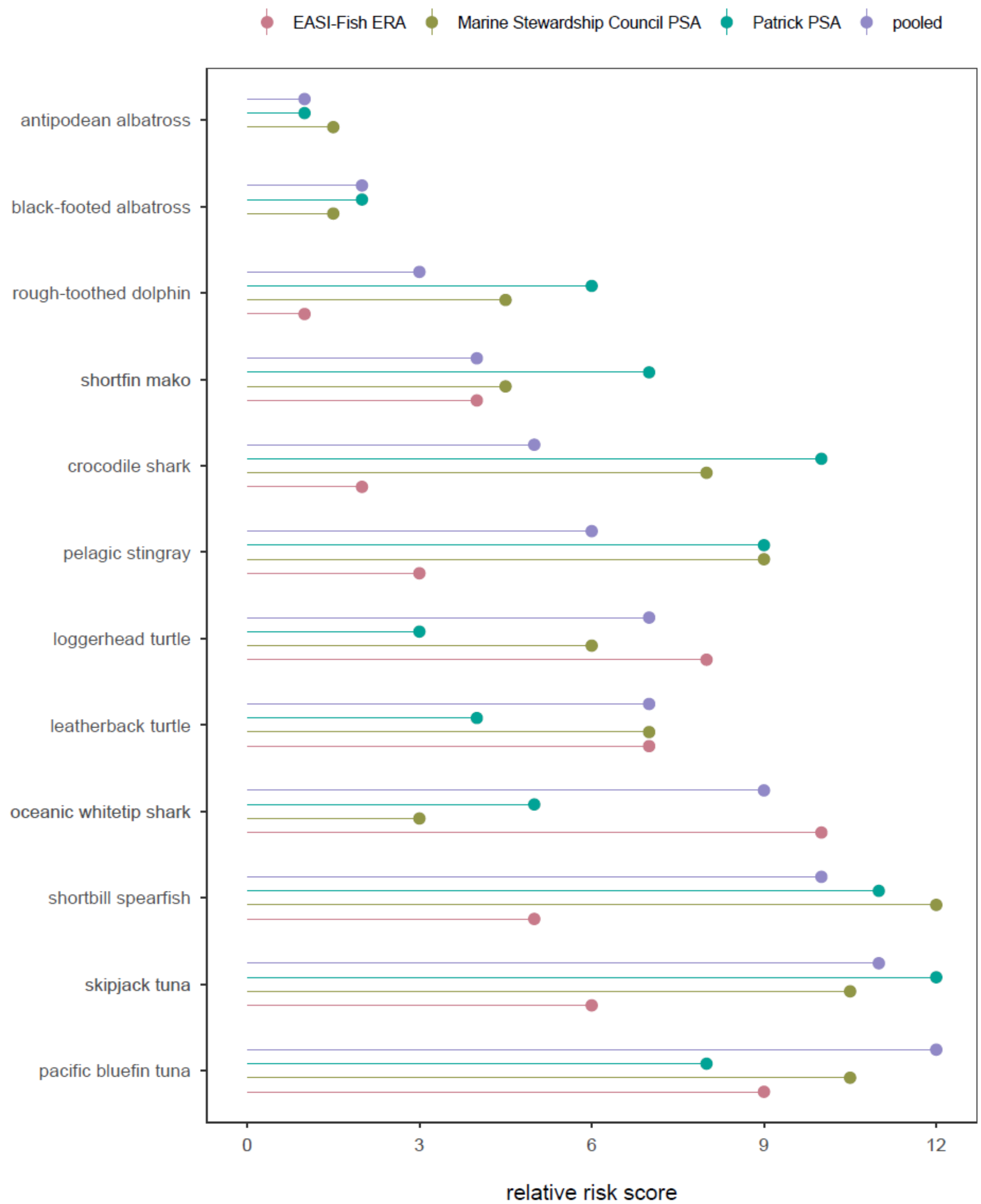

Figure 1. Individual ERA relative risk rank-orders for EASI-Fish, Marine Stewardship Council and Patrick, and overall, pooled relative risk rank order. A rank of 1 indicates highest risk (most vulnerable), and 12 is lowest risk. Stocks/populations are ordered by the overall, pooled rank.

Of 18 fish stocks captured in the Tunago fishery that have undergone stock assessments that produced conclusive or indicative estimates of absolute levels of abundance, exploitation rates, and MSY-based or otherwise proxy reference points, three are likely below biomass limit reference points: Pacific bluefin tuna, WCPO oceanic whitetip shark and WCNPO striped marlin. The effect from mortality in the Thai Union-Tunago fishery of western central north Pacific Ocean striped marlin was identified as a concern and mitigation measures are warranted. While the fishery has a very small level of annual mortality of Pacific bluefin tuna and WCPO oceanic whitetip shark, the small contributions to cumulative, regional fishing mortality may also warrant management interventions.

The study also identified gaps in information on variables that explain catch and post-capture survival risks that if filled would enable a more robust risk assessment. Priorities for improvements in electronic monitoring data quality were also identified. These improvement priorities are discussed in detail in Section 5.

2. OVERVIEW OF PROCESS TO DEVELOP THE TUNAGO-THAI UNION BYCATCH MANAGEMENT PLAN

The steps to develop the Tunago-Thai Union integrated bycatch management strategy are summarized in Figure 2. Details for each step are provided in Table 1.

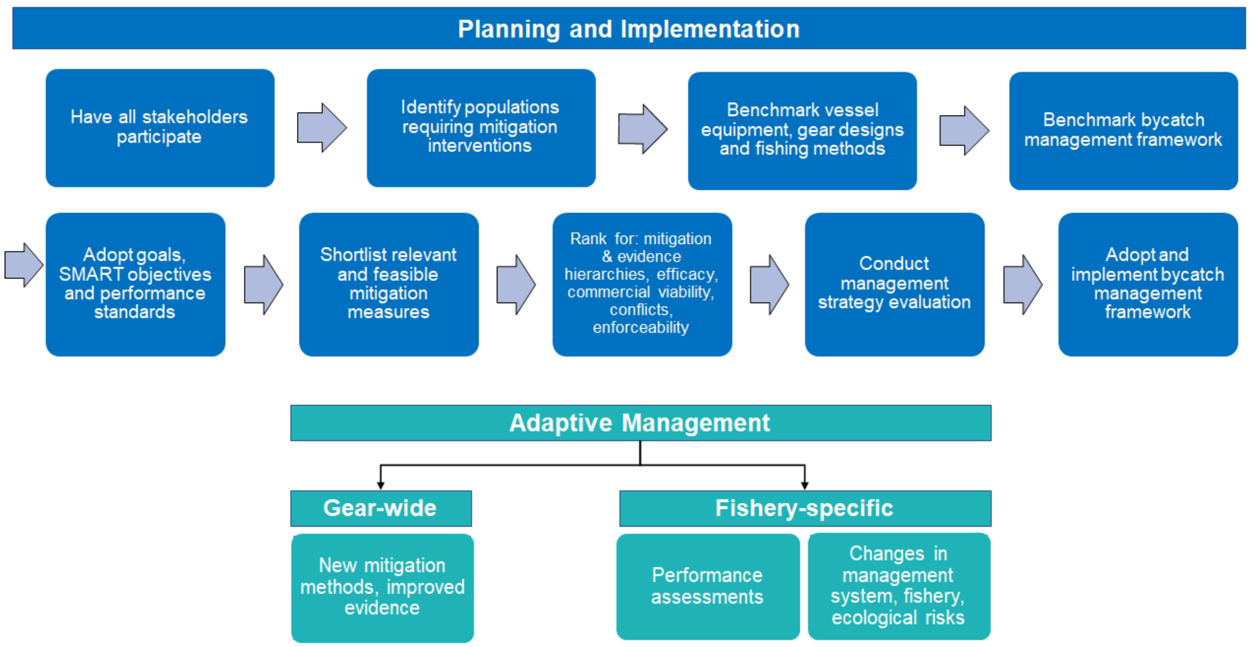

Figure 2. Process to develop the Tunago-Thai Union bycatch management framework (adapted from Gilman et al., 2021a).

Table 1. Summary of steps and outputs to develop the Tunago-Thai Union integrated bycatch management framework (adapted from Gilman et al., 2021a).

Step	Output
Planning & Implementation	
Stakeholder assessment	• Identification and direct involvement of relevant participants in planning and implementing the bycatch management framework, and identification of incentives for bycatch improvements by stakeholder.
Benchmark of contemporary ecological risks and identification of species requiring mitigation interventions	• Identification of relative and absolute risks of populations and stocks susceptible to capture, and scope of the bycatch management strategy based on explicit or otherwise implicit thresholds for acceptable impacts and species-specific fate of the catch.
Benchmark of contemporary fishing practices	• Identification of contemporary vessel equipment, fishing methods and gear designs that significantly explain catch and survival rates of vulnerable bycatch in the gear type used by the fishery.
Benchmark of the contemporary bycatch management framework	• Identification of the current government and voluntary industry bycatch management system, including monitoring, control, surveillance and enforcement systems and the legal and regulatory framework. Identification of findings from available performance assessments of the bycatch management framework and of individual bycatch mitigation measures.
Adoption of goals, objectives and performance standards	• Overarching goals, and objectives and performance standards to achieve the goals, for the bycatch management framework that balance stakeholders' competing priorities, and that are specific, measurable, achievable, relevant and time-oriented, covering: (1) Catch and fishing mortality levels or rates of vulnerable bycatch species, (2) level of residual bycatch removals, or otherwise offsets to achieve no net loss or a net gain; (3) acceptable multispecies conflicts; (4) acceptable commercial viability costs; and (5) improvements in other management components (legal, regulatory, monitoring, surveillance, enforcement).
Shortlist of relevant and feasible bycatch mitigation measures	• Shortlist of candidate bycatch mitigation methods of relevance to the fishery and that can be feasibly implemented
Ranking of bycatch mitigation methods	• Matrix of candidate mitigation methods with weights assigned according to: (1) tiers in mitigation and evidence hierarchies, (2) how they meet objectives for mitigation of catch and mortality rates of vulnerable bycatch species, (3) whether they meet objectives on acceptable multispecies conflicts; (4) whether they meet acceptable effects on commercial viability (practicality, safety, economic viability), and (5) enforceability given the capacity of the fisheries management system to conduct compliance monitoring and the effect of crew behavior on performance of the method.
Implementation of bycatch Management Strategy Evaluation	• Predict the performance of alternative bycatch management frameworks. Identifying frameworks that are likely to achieve objectives on desired improvements in vulnerable bycatch catch

Step	Output
	and mortality rates, and on acceptable multispecies conflicts and commercial viability costs, and compare the tradeoffs amongst objectives that each alternative framework is simulated to produce.
Adoption and implementation of bycatch management framework	• Bycatch management plan adopted, with explicit activities, milestones, schedule, budget, responsible parties, process for independent performance assessments and progress reporting. Implementation may result in new and amended: (1) monitoring, surveillance and enforcement systems; (2) legal and regulatory frameworks, including bycatch measures; and (3) industry measures (company policies, code of practice, sustainable seafood sourcing policies and product specs).
Fishery-specific Adaptive Management	
Periodic, impartial performance assessments	• Performance assessment reports documenting whether the bycatch management program is meeting objectives and milestones.
Identification of new information and developments (findings from performance assessments, improved evidence, new mitigation approaches, changes in objectives, etc.)	• Revised bycatch management framework and other fisheries management components (legal and regulatory framework; monitoring, surveillance and enforcement systems; industry policies, codes of practice, sustainable seafood sourcing policies, product specs).

3. PARTICIPANTS

Of the FIP participants, Thai Union, Key Traceability, Tunago Fishing Company, the Vanuatu Fisheries Department and The Nature Conservancy contributed to the development of this bycatch management strategy and workplan.

Alternative bycatch management methods (described in Section 9) were ranked by Tom Evans (Key Traceability) and Eric Gilman (advisor). A tentative list of alternative external subject matter experts was considered by Thai Union and Key Traceability to participate in the ranking component – individuals with extensive knowledge of alternative methods to mitigate the bycatch of threatened species in pelagic longline fisheries, including the relative degree of efficacy at reducing catch risk and post-capture mortality risk, relative degree of evidence of efficacy, practicality, safety, economic viability, multispecies conflicts, and requirements for compliance monitoring. However, due to time and budget constraints, the FIP lead decided to conduct the ranking without the participation of external experts. The 2022 integrated bycatch management workplan (Section 12) includes an activity to involve external subject matter experts in future ranking of alternative bycatch mitigation methods.

In the future, a stakeholder assessment may help determine whether any groups or companies that are not formal participants of the Thai Union FIP should directly participate in further development and implementation of the bycatch management system – and this is also included as an activity in the bycatch management plan. In general, fisheries stakeholders can include: local, national and regional government fisheries management authorities; community-based and informal fisheries management organizations; companies in the seafood supply chain, which will vary in length and complexity by fishery, and can include producers (catch sector, fisheries associations), intermediaries, processors, exporters and importers, distributors, wholesalers, and end buyers including retailers and foodservice companies; environmental and social non-governmental organizations; and fisheries scientists.

4. POPULATIONS AND STOCKS INCLUDED IN BYCATCH MANAGEMENT PLAN

The Tunago-Thai Union FIP stakeholders selected which populations and stocks are within the scope of the bycatch management strategy and workplan, these being species for which management interventions may be warranted.

Decisions on the selection of populations/stocks and thresholds that trigger management interventions are made easier by having explicitly defined thresholds above which impacts are deemed unacceptable. For some species, a fishery's legal and regulatory framework may define a bycatch threshold that triggers a management response. For example, WCPFC has adopted a marine turtle bycatch rate threshold for shallow-set swordfish longline fisheries (Section S3.2 of Gilman et al., 2021a). Some countries have adopted a *National Plan of Action for Reducing Incidental Catch of Seabirds* that include explicit thresholds that trigger a bycatch management response (Good et al. 2020). Unfortunately, for the Tunago-Thai Union fishery, no such pre-defined thresholds were available.

To help determine which species to include in the bycatch management framework, stakeholders considered whether a species is targeted, incidental catch that has market value and the proportion of the catch of that species that is retained, versus non-marketable catch that is not retained. It is reasonable to expect strong resistance from the catch sector and other supply chain companies to proposals to apply mitigation measures to principal market species. Therefore, stakeholders may decide not to include species of sharks or other relatively vulnerable species in a bycatch mitigation framework if they are primarily retained and critical to the fishery's economic viability, especially if robust harvest strategies and management measures are in place for these species.

The participants also assessed the fisheries management framework to identify existing bycatch thresholds of relevance to the Tunago-Thai Union fishery through the planning step defined in Section 6. For each vulnerable species susceptible to capture in the fishery, stakeholders reviewed national and international measures to determine if thresholds for unacceptable impacts are defined. For this fishery, none of the species have defined thresholds, and therefore stakeholders needed to agree on an approach to determine whether to include them in the bycatch management strategy.

The MSC's Fisheries Standard includes a criterion to avoid and minimize injury and mortality of endangered, threatened and protected (ETP) species that assesses whether a fishery: (1) meets national and international requirements for the protection of the ETP species, and (2) does not hinder the ETP species' recovery (MSC 2018). For ETP species with no national or international limits that trigger a management response, MSC does not provide explicit, quantitative cutoffs for when a fishery hinders recovery or causes unacceptable impacts (MSC 2018). Instead, to determine whether ETP bycatch mitigation actions are required, assessors consider whether direct fishery removals, which includes post-release, ghost fishing and other unobserved mortalities, are 'highly likely to not hinder recovery', which takes into account the fishery's bycatch levels and information on population status and biological reference points, if available. Assessors also consider whether indirect fishery effects, such as reduced prey availability, 'are highly likely to not create unacceptable impacts.' Thus, the MSC fisheries standard lacks an explicit threshold for unacceptable impacts from bycatch of ETP species.

Table 2 lists the stocks and populations affected by the Tunago-Thai Union fishery, and the subset that participants decided to include in the bycatch plan, and the basis for the decision. The FIP's MSC pre-assessment and ETP Management Strategy (Key Traceability, 2020a,b) and the Tunago ecological risk assessment (Gilman et al., 2021b) were used to compile the list of stocks and populations that are categorized as ETP species and/or are relatively vulnerable and taken in the Tunago-Thai Union fishery. Species groups are listed in descending order based on the assessment of relative and absolute vulnerability from the Tunago-Thai Union fishery from the risk assessment of Gilman et al. (2021b). Based on findings from this ecological risk assessment, and based on a precautionary approach due to the current data-limited nature of the fishery, the FIP participants prioritized management and mitigation of catch and mortality of:

- All populations of Pacific Ocean albatrosses
- WCPO stock of oceanic whitetip shark
- Odontocetes
- All Pacific populations of leatherback, loggerhead, olive Ridley, hawksbill and green marine turtles
- Mesopelagic and silky sharks
- Pelagic stingray, Pacific Ocean populations
- WCNPO stock of striped marlin
- Pacific bluefin tuna

Table 2. List of candidate stocks and populations for inclusion in the bycatch plan, identification of which were selected for inclusion, and the basis for the decision.

Stock, Population or Species	Include in Bycatch Plan?	Justification
Seabirds		
Populations of ACAP-listed albatross and petrel species that occur in the Pacific	Y	Seabirds on the ACAP Species List are categorized as ETP species under MSC. Seabirds are classified by MSC as "out-of scope" and most of the ACAP-listed species are listed in the IUCN Red List as threatened. Albatrosses were the most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b).
Cetaceans		
Rough-toothed dolphin, Pacific populations	Y	While the rough-toothed dolphin global conservation status is listed in the IUCN Red List as least concern, the status of individual populations that overlap the Tunago-Thai Union fishery is unknown. Cetaceans were the 2nd most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b).

		No marine mammal captures were recorded by an EM analyst (from 1 EM trip, Gilman et al., 2021b). This species was the predominant marine mammal captured in the entire Vanuatu longline fishery (Vanuatu Fisheries Department, 2019) and one of the most frequent cetacean species captured in regional longline fisheries of the Western and Central Pacific Fisheries Commission Convention Area (Williams et al., 2020).
False killer whale, Pacific populations	Y	Included in the *ETP Management Strategy* (Key Traceability, 2020a). The false killer whale is listed in the IUCN Red List as near threatened. Cetaceans were the 2nd most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b).
Sperm whale, Pacific populations	Y	Included in the *ETP Management Strategy* (Key Traceability, 2020a). The sperm whale is listed in the IUCN Red List as vulnerable. Cetaceans were the 2nd most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b).
Short-finned pilot whale, Pacific populations	Y	Included in the *ETP Management Strategy* (Key Traceability, 2020a). While the short-finned pilot whale global status is listed in the IUCN Red List as least concern, the status of individual populations that overlap the Tunago-Thai Union fishery is unknown. Cetaceans were the 2nd most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b).
Common dolphin, Pacific populations	Y	Included in the *ETP Management Strategy* (Key Traceability, 2020a). Although the common dolphin's global status is listed in the IUCN Red List as least concern, the status of individual populations that overlap the Tunago-Thai Union fishery is unknown. Cetaceans were the 2nd most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b).
Melon-headed whale, Pacific populations	Y	Included in the *ETP Management Strategy* (Key Traceability, 2020a). Although the melon-headed whale global status is listed in the IUCN Red List as least concern, the status of individual populations that overlap the Tunago-Thai Union fishery is unknown.

		Cetaceans were the 2nd most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b).
Deeper-habitat Sharks		
Blue shark, north and south Pacific Ocean stocks	Y	Although this is a retained species in this fishery (97% retained of 226 captured from 1 EM trip, Gilman et al., 2021b), the participants decided to include it in the bycatch management plan. Mesopelagic sharks were the 3rd most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b). 0.78% of number of total catch; catch rate of 0.3 per 1000 hooks (from 1 EM trip, Gilman et al., 2021b) – noting however that the EM analyst was unable to identify to the species level a large proportion of the shark catch. List on CMS Appendix II.
Mako sharks, Pacific Ocean stocks	Y	Although this is a retained species in this fishery (85% retained of 48 captured from 1 EM trip, Gilman et al., 2021b), the participants decided to include it in the bycatch management plan. Mesopelagic sharks were the 3rd most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b). 0.17% of number of total catch; catch rate of 0.06 per 1000 hooks (from 1 EM trip, Gilman et al., 2021b) – noting however that the EM analyst was unable to identify to the species level a large proportion of the shark catch. Listed on CMS Appendix II.
Thresher sharks, Pacific Ocean stocks	Y	33% (1 of 3) retained (from 1 EM trip, Gilman et al., 2021b). Mesopelagic sharks were the 3rd most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b). 0.01% of number of total catch; catch rate 0.004 per 1000 hooks (from 1 EM trip, Gilman et al., 2021b) – noting however that the EM analyst was unable to identify to the species level a large proportion of the shark catch. Listed on CMS Appendix II.
Rays		
Pelagic stingray, Pacific Ocean stocks	Y	Rays were the 4th most vulnerable group from a risk assessment of the Tunago-Thai Union fishery (Gilman et al., 2021b).

		0% retained. 5.2% of number of total catch; catch rate 2 per 1000 hooks (from 1 EM trip, Gilman et al., 2021b).
Giant manta, Pacific Ocean stocks	Y	Listed on CMS Appendix I and CITES Appendix II
Marine Turtles		
Loggerhead, olive Ridley, hawksbill and green, Pacific Ocean populations	Y	The loggerhead, olive ridley, hawksbill, and green turtles are listed in the IUCN Red List as threatened. Fishery does not overlap the distributions of Kemp's ridley or flatback turtles. Listed on CMS Appendix I and CITES Appendix I
Leatherback, Pacific Ocean populations	Y	The leatherback turtle is listed in the IUCN Red List as threatened. Listed on CMS Appendix I and CITES Appendix I
Shallower-habitat Sharks		
WCPO and EPO silky shark	Y	WCPFC retention ban and broad shark conservation measure (WCPFC, 2019) Listed on CMS Appendix II (CMS, 2020) 0.003% of number of total catch; catch rate 0.0001 per 1000 hooks (from 1 EM trip, Gilman et al., 2021b) – noting however that the EM analyst was unable to identify to the species level a large proportion of the shark catch.
WCPO and EPO oceanic whitetip shark	Y	WCPFC retention ban and broad shark conservation measure (WCPFC, 2019) IATTC retention ban (IATTC, 2011b) Listed on CMS Appendix I (CMS, 2020) None observed captured during 1 EM trip (Gilman et al., 2021b) – noting however that the EM analyst was unable to identify to the species level a large proportion of the shark catch.
Teleosts		
Western central north Pacific Ocean (WCNPO) striped marlin	Y	Although this is a retained species - 70% of 70 captured striped marlins were retained (from 1 EM trip, Gilman et al., 2021b), the participants decided to include it in the bycatch management plan. The fishery's contribution to cumulative fishing mortality of WCNPO striped marlin may be a concern (Gilman et al., 2021b). The Tunago-Thai Union fishery annually captures a very rough estimate of 30 t, which is 1.4% of the weight of the total mean annual estimated catch. The stock may be below a biological limit threshold ($SSB/SSB_{F=0}$ = 0.054, SSB_{recent}/SSB_{MSY} = 0.38) and not rebuilding. Mortality in longline fisheries has accounted

		for almost all WCNPO striped marlin fishing mortality since the early 1990s.
Pacific bluefin tuna	N	Available, limited data suggest that the Tunago fishery has only a nominal effect on this stock (Gilman et al., 2021b). Cumulative effects of regional longline fishing mortality of Pacific bluefin tuna are small, where <10% of total catch is by regional longline fisheries.

5. CONTEMPORARY FISHING PRACTICES

Participants compiled available information on contemporary fishing methods and gear designs that significantly explain catch and survival rates of vulnerable bycatch. This information is summarized in Appendix 1, where, for each pelagic longline bycatch mitigation method that is related to a fishing method or gear design, column 2 identifies whether the method is currently being implemented.

Information on hooks per set, hooks per float, soak duration, time-of-day of initiating setting, gear soak duration, tori line use during setting, and fate of the catch were derived from an electronic monitoring dataset from one trip (Gilman et al., 2021b). Information on bait and hook type were from Key Traceability (2020a). Information on leader material and shark line use is based on company policy (Tunago, 2019). Information on other gear designs (lightstick use, branchline and floatline length, branchline weighting design, and distance between the point of attachment of the first branchline and floatline) were obtained from Tunago skippers in November 2021.

- **Hooks per set:** Mean 3,337
- **Hooks per float**: Mean 10.6 (range 10 to 12)
- **Gear maximum soak duration**: Mean 20.6 hours (range 6.2 to 23.9 hours) (total elapsed time between the start of the set and end of the haul).
- **Time-of-day initiate set**: mean 14:11 (range 9:52 to 19:32)
- **Bait type**: Small forage fish species, including saury and mackerels
- **Hook shape and size**: Circle hook, 10-degree offset, 4.6 cm narrowest width.
- **Tori-lines**: Tori lines are used in areas where required by IATTC and WCPFC (north of 23 degrees N, south of 25 degrees S, IATTC, 2011a; WCPFC, 2018).
- **Leader material**: Monofilament leaders
- **Shark line use**: Shark lines (shallow-set branchlines attached to floats or floatlines) are not used.
- **Lightsticks**: Not used.
- **Branchline length**: Between 20 and 27 m.
- **Floatline length**: Between 25 and 30 m.
- **Mass of branchline weights:** 50 g or 60 g.
- **Type of branchline weight:** Conventional lead-centered swivel, crimped in place onto the branchline monofilament line.
- **Leader length:** Between 12 and 13 m (distance between the hook and weight).
- **Distance between the point of attachment of the first branchline and floatline**: Between 35 and 38 m.
- **Retention ban compliance**: No retention of oceanic whitetip and silky sharks in all areas.

- **Shark finning:** All retained sharks include the carcass with fins naturally attached –shark finning is prohibited.
- **Night setting in areas where tuna RFMOs require the employment of seabird bycatch mitigation methods**: The tuna RFMO seabird measure definition of night setting may not be routinely implemented. When fishing in areas where seabird bycatch mitigation methods are required to be used, the EM dataset indicated that sets made in these areas did not meet night setting definition, as setting occurred between local sunrise and local sunset.
- **Electronic tracking of gear position**: Radio buoys are deployed in the gear when fishing to enable tracking the position to reduce the risk of loss.

Several additional variables understood to effect catch and mortality rates in pelagic longline fisheries were not available for the Tunago-Thai Union fishery (Appendix 1). Collection of this information is included as a priority activity in the bycatch management plan.

6. CONTEMPORARY BYCATCH MANAGEMENT FRAMEWORK

Knowledge of the bycatch management system enables participants to identify which taxon-specific bycatch mitigation controls are in place and to then identify additional options not already being employed. Benchmarking the bycatch governance system also enables stakeholders to determine the suitability of alternative mitigation measures for compliance monitoring given the current capacity of the monitoring, surveillance and enforcement systems.

6.1. Monitoring Systems – Electronic Monitoring, At-Sea Observers, VMS, Logbooks, Port Sampling

Information on monitoring of the Tunago-Thai Union fishery is summarized in the FIP's MSC pre-assessment, Action Plan and ETP Management Strategy (Key Traceability, 2020a,b,c) as well as the Vanuatu government's part 1 annual report to WCPFC (Vanuatu Fisheries Department, 2021). Current Vanuatu government monitoring of the Tunago vessels is through satellite-based vessel monitoring systems (VMS), a logbook program (estimated 62% coverage), and possibly limited port sampling (Vanuatu Fisheries Department, 2021). The Tunago fishery has also been piloting EM systems on fishing and transshipment vessels, but has to date not been used by the national fisheries management authority as part of their longline fisheries monitoring framework (Vanuatu Fisheries Department, 2019). The Vanuatu government in the past has stated plans to achieve 5% observer coverage of non-locally-based longline vessels, and 100% observer coverage of vessels making at-sea transshipment (Vanuatu Fisheries Department, 2014).

There is a need to obtain information on the human observer coverage rate of the Tunago-Thai Union fleet over the past 5 years, and if any observer coverage occurred, to assess data quality, including a gap analysis of data fields that enable identifying factors that significantly explain bycatch and mortality rates, assessing the performance of any bycatch management measures, and monitoring compliance with any bycatch mitigation measures.

The 2022 bycatch management plan calls for meeting 20% EM or human observer coverage by the end of the calendar year. To avoid statistical sampling bias, the necessary observer or EM coverage rate, as well as data fields and data collection methods, for a particular fishery depend on: (1) the objectives of analysis, including required levels of accuracy and precision of catch rates, and (2) aspects of each individual fishery – such as how many vessel classes exist, how many ports are used, the spatial and temporal distribution of effort, the frequency of occurrence of catch interactions for each species of interest, the amount of fishing effort, and the spatial and temporal distribution of catch (Babcock et al. 2003; Wakefield et al. 2018). In general, variability in precision and biases in bycatch estimates decrease rapidly as the observer coverage rate increases to about 20%, assuming that the sample is balanced and there are no observer effects, and then decrease slowly towards 0 with 100% coverage (Lennert-Cody 2001; Lawson 2006). At lower coverage rates, catch estimates will likely have large uncertainties for species with low capture rates (Amande et al. 2012), and may result in high uncertainty even for species that are more commonly caught if a small sample size is observed per stratum (e.g., by port, vessel category, season) (Bravington et al. 2003). When low coverage rates result in small sample sizes, it is very likely that rare species susceptible to capture, some of which may be relatively vulnerable, will not be identified. Species richness and other species-level biodiversity indices are extremely sensitive to sample size and species abundance distribution (evenness). The less even the relative abundance of species in a community is, the larger the proportion of relatively rarer species within that system will be detected with more sampling effort.

6.2. Legal, Regulatory, Control, Surveillance and Enforcement Systems

The contemporary fisheries management framework related to bycatch for the Tunago-Thai Union fishery is summarized in the FIP's MSC pre-assessment, Action Plan and ETP Management Strategy (Key Traceability, 2020a,b,c) as well as the Vanuatu government's part 1 annual report to WCPFC (Vanuatu Fisheries Department, 2021). Additional information on Vanuatu's fisheries management framework was obtained from the most current national plans of action on sharks and seabirds (Vanuatu Fisheries Department, 2015; Vanuatu Fisheries Department and FFA, 2015), and from the Vanuatu Fisheries Act No. 10 of 2014 and Fisheries Regulation Order No. 28 of 2009, as amended (Republic of Vanuatu, 2009, 2014). Note, the current shark and seabird NPOAs expired in 2018 and 2020, respectively.

Voluntary company policy bans the use of shark lines, wire leaders and shark finning (Tunago, 2019). The Vanuatu national fisheries management authority's measures related to bycatch are as follows (Republic of Vanuatu, 2009, 2014; Vanuatu Fisheries Department, 2015; Vanuatu Fisheries Department and FFA, 2015):

- In Vanuatu waters, ban on shark targeted fishing by longline vessels;
- In Vanuatu waters, shark catches must be ≤10% of the total catch in one trip;
- In Vanuatu waters, ban on fishing within 3 nm of the center of seamounts;
- In Vanuatu waters, ban on shark finning (retaining only the fins of sharks), and retained sharks must have fins naturally attached;
- In Vanuatu waters, ban on the use of wire leaders;
- In Vanuatu waters, ban on the retention of oceanic whitetip sharks; and
- Required compliance with all relevant binding measures of RFMOs where Vanuatu is a member, including IATTC and WCPFC.

A current Vanuatu longline license was not available for this assessment and is identified in the bycatch plan as a priority information gap to augment the assessment of the contemporary domestic longline fisheries management framework.

There was a gap in information for this assessment on the Vanuatu government's recent surveillance activities, including dockside and at-sea inspections, identified infractions, the proportion of identified infractions that resulted in penalties, and what penalties were issued by the Vanuatu government. Addressing this priority information gap is included as an activity in the bycatch management plan, and will be conducted by the MSC-accredited conformity assessment body for the full assessment against the MSC fisheries standard.

An assessment of the government and voluntary industry management framework enabled a preliminary determination of whether incentives for compliance with required bycatch management measures are adequate to deter non-compliance. Measures that provide economic and social incentives to implement practices that mitigate bycatch are necessary enabling preconditions for effective bycatch management programs. Bycatch mitigation can be incentivized through a broad range of combinations of penalties and rewards through government fisheries management frameworks as well as through market-based mechanisms. Economic, market-based reputational measures which rely on negative incentives include: closure of part or all of fishing grounds, required use of bycatch mitigation measures or more stringent methods, purchase of bycatch quota, levy (tax) assessed per defined bycatch unit, reduced or withheld subsidies, higher permit or license fee, higher tax rate, reduced quota for target species, not achieving or losing certification against an ecological fisheries sustainability standard, lower FIP ranking, and negative media coverage. Reward-based measures include the converse of these penalties, such as the sale of unused bycatch quota, provision of a subsidy or increased subsidy, etc. (Gilman et al., 2021a).

7. GOALS, SMART OBJECTIVES AND PERFORMANCE STANDARDS

Stakeholders defined overarching goals and explicit objectives and performance standards to achieve the goals for the bycatch management framework. This was informed by information from previous steps on contemporary bycatch relative risks, the identification of which populations and stocks warrant bycatch mitigation interventions, and contemporary fishing practices and governance system.

A main overarching goal for this bycatch management plan is to reach a point where the fishery would score at least 80 when assessed against each performance indicator on ETP species under principle 2 of the MSC fisheries standard. For each ETP species, the fishery must (1) meet national and international requirements for the protection of the ETP species, and (2) be highly unlikely to hinder the recovery of the ETP species – by the individual Tunago-Thai Union fishery and from cumulative effects of MSC certified fisheries.

Stakeholders agreed to consider, at a later date, the possibility of amending the goal to meet a ‘bycatch neutral’ no net loss objective, where, similar to carbon offset programs, residual adverse impacts on biodiversity that are not avoided and minimized may be offset by obtaining an equivalent gain, or a more-than-equivalent net gain (Coralie et al. 2015; Maseyk et al. 2016; Booth et al. 2021). This was included as a future activity in the bycatch plan. Examples of approaches to achieve bycatch offsets are reviewed in Section 8.

Bycatch management objectives are defined to be specific, measurable, achievable, relevant and time-oriented (SMART). They were developed following a process that was suitable to the fishery-specific context. The scope of the bycatch management objectives covers:

1. Catch and post-capture mortality levels or rates for vulnerable bycatch species;
2. Acceptable tradeoffs from multispecies conflicts;
3. Acceptable costs to commercial viability (practicality, economic viability, crew safety); and

4. Requisite improvements in legal and regulatory frameworks to enable components of a robust bycatch management framework; in monitoring and surveillance systems to enable adequate compliance monitoring and performance assessments of the adopted bycatch management framework; and in the enforcement framework to ensure it adequately incentivizes fisher compliance.

For each objective, stakeholders defined milestones that support achieving the objective. Objectives are summarized by taxonomic group, from highest to lowest risk as defined in Section 4, except that pelagic stingray is combined with the epipelagic sharks group.

To be achievable, the selected objectives and milestones accounted for the capabilities of the fisheries management system, including data quality. For instance, as a data-limited fishery with a very short time series and size of observer and EM program coverage, at this stage, it is not feasible to employ a bycatch mitigation measure that restricts fishing at spatially and temporally predictable bycatch hotspots for rare-event captures.

For individual fisheries where contributions to cumulative anthropogenic mortality of stocks and populations are nominal, stakeholders may still define an objective based on a change in bycatch and mortality levels, or could define the objective based on changes in bycatch rates and at-vessel, at-release and post-release mortality rates (where for the latter, indicators of probability of post-release survival could be employed). However, for individual fisheries with mortality levels that do significantly impact population viability, objectives based on bycatch *rates* will be ineffective if they do not account for the effect of changes in other variables that affect fishing mortality *levels* and for changes in population status.

Stakeholders defined acceptable impacts on economic viability, such as what reduction in catch rates of marketable species and in fishing effort are acceptable. Evaluating the effect of different bycatch measures on the bycatch/target catch ratio enables assessing tradeoffs between bycatch minimization and target catch optimization objectives. Stakeholders identified improvements in monitoring, surveillance and enforcement systems, and in the legal and regulatory frameworks, that they anticipate being required to meet the objectives.

In a subsequent step in Section 12, stakeholders will use these objectives and performance standards to develop the bycatch management framework, which will define explicit actions, milestones (outcomes) resulting from each action, a schedule for implementing the actions and achieving each milestone, and who is responsible to implement each activity. **Thus, the list of milestones included within each taxonomic group is partial – additional milestones are defined in the bycatch plan defined in Section 12 associated with specific activities.** These explicit objectives, milestones and schedule support periodic performance assessments, where findings will be used to adapt the management framework in the final decision tool step.

7.1. Objectives, Performance Standards and Milestones – Seabirds

Objective and performance standard – seabird bycatch management: Cap the capture rate of combined albatrosses and petrels to the most recent 3-year mean, to be determined once 3-years of EM and/or human observer monitoring data are available and are collected from vessels that were in compliance with relevant tuna RFMO seabird measures, where no 5-year mean combined albatross and petrel catch rate is to exceed this cap.

Note: The current available estimated mean combined albatrosses and petrels catch rate is 0.54 per 1000 hooks, estimated from 1 EM trip conducted in 2019. Available information suggests that the vessel was in compliance with the seabird measure of IATTC. Under IATTC Resolution C-11-02, when south of 30 S (plus an additional area along the coast of south America) and north of 23 N, using a tori line that meets the minimum specifications and a mainline line shooter enables a vessel to meet the measure. However, the vessel was not in compliance with the WCPFC seabird measure CMM 2018-03, when south of 30 S, where vessels must use two of: tori line, weighted branchlines, or night setting, or use hook-shielding devices. The Tunago vessel may have used tori lines, but did not meet the other measures. The Tunago vessel was in compliance with the WCPFC measure in other areas where seabird bycatch mitigation methods are required (between 25 S and 30 S, and north of 23 N). Based on the assumption that the Tunago vessels will begin to employ tori lines and weighted branchlines. Under WCPFC CMM 2018-03, the options are: (1) 40 g within 0.5 m of the hook, (2) 45 g within 1 m of the hook, (3) 60 g within 3.5 of the hook, and (4) 98 g within 4 m of the hook. However, in the northern hemisphere, options 1 is recommended due to the diving capacity albatross species in this region (see Gilman et al., 2020). Until adequate information is available to define the seabird objective cap, the fishery will use 0.45 combined albatross and petrel captures per 1000 hooks as an interim cap.
Caveat 1: If the information collected to meet the milestones, defined below, indicate that the vessels have not been in compliance with the RFMO seabird measures, then three years of monitoring data will need to be collected with the vessels employing measures that bring them into compliance with the RFMO seabird measures to define the catch rate threshold.
Caveat 2: If more rigorous IATTC or WCPFC seabird measures are adopted, then once three years of monitoring data are available from the Tunago-Thai Union vessels when in compliance with the amended RFMO seabird measures, if the mean combined albatross and petrel catch rate declines, then the cap will be reset to this lower catch rate estimated mean.

Objective – Costs from multispecies tradeoffs: Because there are numerous effective seabird bycatch mitigation methods available for pelagic longline fisheries that do not pose a risk of increased catch or mortality rate of other ETP species, no costs from multispecies conflicts are acceptable. However, if at a future date a seabird bycatch mitigation method is identified as being necessary to achieve the seabird bycatch objective that causes multispecies conflicts, such as night setting (which would require a change in fishing depth), then the participants will reconsider the objective for multispecies costs.

Objective – Costs to commercial viability: Participants accept minor increased costs to crew safety and practicality from the employment of seabird bycatch mitigation methods to comply with binding IATTC and WCPFC seabird measures. No economic costs from changes in fish catch rates are acceptable. Costs to purchase and maintain equipment to employ seabird bycatch mitigation methods are acceptable.

Objective – Fisheries management system improvements to monitoring, control, surveillance, enforcement, outcomes of enforcement actions:

- Monitoring: A minimum of 20% at sea monitoring by EM or human observers. All vessels must have EM systems that meet RFMO minimum standards (once adopted), and a random sample of a minimum of 20% of EM data are analyzed annually, or less than 20% is permissible if human observer coverage brings the annual total monitoring to at least 20% of effort.
- Control: Vanuatu regulations and/or license agreements implement relevant IATTC and WCPFC binding measures.

- Surveillance: Surveillance methods are employed by Vanuatu government that enable robust compliance monitoring of each bycatch mitigation method selected for this taxonomic group.
- Enforcement: There is no evidence of systematic lack of enforcement of identified infractions.
- Outcomes of enforcement actions: Penalties resulting from enforcement actions are sufficient to deter non-compliance. Vessels with 2 or more identified infractions will have 100% monitoring (EM or human observer) for the next two years.

Milestone 1: By January 2022, stakeholders will analyze available EM and observer data to define the cap per the method defined in the objective statement.

Milestone 2: Annually, the current 3-year mean combined albatross and petrel catch rate will be estimated, and if it exceeds the cap, then more robust combinations of seabird bycatch mitigation methods will be employed.

Milestone 3: By December 2022, and in all subsequent years, all vessels will have EM systems installed, and a minimum of a 20% monitoring rate (≥20% of trips), through EM, human observers, or a combination of these two methods, will be achieved. The EM systems will meet IATTC and WCPFC EM standards, if adopted by this date or otherwise when adopted.

Milestone 4: By December 2022, the species level of the seabird catch will be achieved for monitoring programs for ≥66% of seabirds retrieved during the gear haulback.

Milestone 5: By December 2022, analyses of EM data and complementary dockside monitoring will be conducted by the Vanuatu government to determine compliance with IATTC and WCPFC seabird measures and adopted by this bycatch management plan.

Milestone 6: By December 2022, the Vanuatu control, surveillance, enforcement and outcomes of enforcement actions will meet the fisheries management objective defined above. Compliance monitoring may be achieved through a combination of EM analysis and dockside inspections Penalties from infractions that are sufficient to deter non-compliance are set at USD $200,000 per infraction.

7.2. Objectives, Performance Standards and Milestones – Marine Mammals

Objective and performance standard – marine mammal bycatch management: Same as for seabirds.
Note: No marine mammals were recorded by the EM analyst for 1 analyzed trip in 2019. Until adequate information is available to define the objective cap, based on estimated marine mammal catch rates of the entire Vanuatu-flagged longline fishery, the fishery will use 2 combined marine mammal captures per 235 sets, ca. 1 trip by a Tunago vessel, as an interim cap.

Objective – Costs from multispecies tradeoffs: Only small costs from multispecies conflicts are acceptable from the implementation of bycatch mitigation methods for marine mammals. Of the full suite of options included in Appendix 1, encasement of catch could result in substantial adverse effects on other ETP species, and this option was not shortlisted by the participants. Except potentially for some area-based management tools, all other options specific to mitigating marine mammal catch and fishing mortality would either have no effect or reduce catchability of other ETP species.

Objective – Costs to commercial viability: Participants accept minor increased costs to crew safety and practicality from the employment of marine mammal bycatch mitigation methods. The effect of combined mitigation measures to manage marine mammal, marine turtle, elasmobranch and striped marlin bycatch can result in a reduction in catch rates of the number of combined retained species per 1000 hooks of up to 1.5%. Costs to purchase and maintain equipment to employ marine mammal bycatch mitigation methods are acceptable.

Objective – Fisheries management system improvements to monitoring, control, surveillance, enforcement, outcomes of enforcement actions:
Same as for seabirds.

Milestone 1: Same as for seabirds.

Milestone 2: Same as for seabirds, but for combined marine mammal species.

Milestone 3: Same as for seabirds.

Milestone 4: Same as for seabirds.

Milestone 5: By December 2022, analyses of EM data and complementary dockside monitoring will be conducted by the Vanuatu government to determine the degree of compliance with bycatch mitigation measures for marine mammals adopted by this bycatch management plan.

Milestone 6: Same as for seabirds.

7.3. Objectives, Performance Standards and Milestones – Mesopelagic Sharks

Objective and performance standard – mesopelagic shark bycatch management: Same as for seabirds.
Note: The current available estimated mean combined mesopelagic shark catch rate is 0.6 per 1000 hooks, estimated from 1 EM trip conducted in 2019, when assuming captured sharks not identified to the species level were mesopelagic species. Until adequate information is available to define the objective cap, the fishery will use 0.6 combined mesopelagic shark captures per 1000 hooks as an interim cap.

Objective – Costs from multispecies tradeoffs: Only small costs from multispecies conflicts are acceptable from the implementation of bycatch mitigation methods for mesopelagic sharks. Of the full suite of options included in Appendix 1, fishing shallower at night and switching from circle to J-shaped hooks were not shortlisted, and the remaining shark mitigation options, except potentially for some area-based management tools, would either have no effect or reduce catchability of other ETP species.

Objective – Costs to commercial viability: See marine mammals.

Objective – Fisheries management system improvements to monitoring, control, surveillance, enforcement, outcomes of enforcement actions: Same as for seabirds.

Milestone 1: Same as for seabirds

Milestone 2: Same as for seabirds, but for combined mesopelagic shark species

Milestone 3: Same as for seabirds

Milestone 4: By December 2022, the species level of the catch will be achieved for monitoring programs for ≥80% of mesopelagic sharks captured during the gear haulback.

Milestone 5: By December 2022, analyses of EM data and complementary dockside monitoring will be conducted by the Vanuatu government to determine the degree of compliance with bycatch mitigation measures for mesopelagic sharks adopted by this bycatch management plan.

Milestone 6: Same as for seabirds.

7.4. Objectives, Performance Standards and Milestones – Marine Turtles

Objective and performance standard – marine turtle bycatch management: Same as for seabirds.
Note: The current available estimated mean combined marine turtle catch rate is 0.003 per 1000 hooks, estimated from 1 EM trip conducted in 2019. Until adequate information is available to define the objective cap, the fishery will use this rate as an interim cap.

Objective – Costs from multispecies tradeoffs: The increase in catch rates of individual species of mesopelagic sharks cannot exceed 10% (using the most recent 3-year mean) as the result of employing mitigation methods that reduce the catchability of epipelagic species (marine turtles, epipelagic sharks, pelagic stingray, striped marlin). The increase in catch rates of individual species of epipelagic sharks and of pelagic stingray cannot exceed 10% (using the most recent 3-year mean) as the result of employing other mitigation methods that reduce the catchability of marine turtles. No marine turtle bycatch mitigation methods are expected to adversely affect seabird or marine mammal catch or mortality risk.

Objective – Costs to commercial viability: See marine mammals.

Objective – Fisheries management system improvements to monitoring, control, surveillance, enforcement, outcomes of enforcement actions: Same as for seabirds.

Milestone 1: Same as for seabirds

Milestone 2: Same as for seabirds, but for combined marine turtle species

Milestone 3: Same as for seabirds

Milestone 4: Same as for seabirds.

Milestone 5: By December 2022, analyses of EM data and complementary dockside monitoring will be conducted by the Vanuatu government to determine the degree of compliance with bycatch mitigation measures for marine turtles adopted by this bycatch management plan.

Milestone 6: Same as for seabirds.

7.5. Objectives, Performance Standards and Milestones – Epipelagic Sharks and Pelagic Stingray

Objective and performance standard – epipelagic sharks and pelagic stingray bycatch management: Same as for seabirds.
Note: The current available estimated mean combined epipelagic shark catch rate is 0.27 per 1000 hooks, estimated from 1 EM trip conducted in 2019, when assuming captured sharks not identified to the species level were mesopelagic species. The current available pelagic stingray catch rate is 1.9 per 1000 hooks. Until adequate information is available to define the objective cap, the fishery will use these rates as interim caps.

Objective – Costs from multispecies tradeoffs: Same as for marine turtles.

Objective – Costs to commercial viability: See marine mammals.

Objective – Fisheries management system improvements to monitoring, control, surveillance, enforcement, outcomes of enforcement actions: Same as for seabirds.

Milestone 1: Same as for seabirds

Milestone 2: Same as for seabirds, but for combined epipelagic shark and pelagic stingray species

Milestone 3: Same as for seabirds.

Milestone 4: Same as for mesopelagic sharks.

Milestone 5: By December 2022, analyses of EM data and complementary dockside monitoring will be conducted by the Vanuatu government to determine the degree of compliance with bycatch mitigation measures for epipelagic sharks and pelagic stingray adopted by this bycatch management plan.

Milestone 6: Same as for seabirds.

7.6. Objectives, Performance Standards and Milestones – WCNPO Striped Marlin

Objective and performance standard – striped marlin bycatch management: Same as for seabirds.
Note: The current available estimated mean striped marlin catch rate is 0.36 per 1000 hooks, estimated from 1 EM trip conducted in 2019, when assuming captured istiophorid fishes not identified to the species level were striped marlins. Until adequate information is available to define the objective cap, the fishery will use this rate as an interim cap.

Objective – Costs from multispecies tradeoffs: Same as for marine turtles.

Objective – Costs to commercial viability: See marine mammals.

Objective – Fisheries management system improvements to monitoring, control, surveillance, enforcement, outcomes of enforcement actions: Same as for seabirds.

Milestone 1: Same as for seabirds

Milestone 2: Same as for seabirds, but for striped marlin.

Milestone 3: Same as for seabirds

Milestone 4: By December 2022, the species level of the catch will be achieved for monitoring programs for ≥80% of istiophorid billfishes captured during the gear haulback.

Milestone 5: By December 2022, analyses of EM data and complementary dockside monitoring will be conducted by the Vanuatu government to determine the degree of compliance with bycatch mitigation measures for striped marlin adopted by this bycatch management plan.

Milestone 6: Same as for seabirds.

8. SHORTLISTED BYCATCH MITIGATION METHODS

The participants reviewed an exhaustive database of bycatch mitigation methods for pelagic longline fisheries (Appendix 1) and identified those to retain as a shortlist. Participants created a short list of bycatch mitigation methods by determining which methods are relevant and feasible for implementation in the fishery by considering:

1. The populations selected for inclusion in the bycatch management plan;
2. Contemporary fishing practices;
3. The contemporary bycatch management framework, including monitoring, control, surveillance and enforcement systems and the legal and regulatory framework; and
4. Stakeholders' agreed objectives for the bycatch management system.

Some of the bycatch mitigation methods included in Appendix 1 are specific to pelagic longline gear, and some are taxa-specific – such as managing leader material to reduce shark catchability and using a tori line to reduce seabird catchability. There are also a variety of broadly applicable bycatch mitigation approaches that are not specific to a particular gear type or species. This includes input (effort) and output (quotas, TACs, and total allowable bycatch quotas or TABQs, see Supplemental Material Section S2 in Gilman et al., 2021a) controls; area-based management tools ranging from static and permanent no-take marine protected areas to temporally- and spatially-dynamic closures; and fleet communication and move-on rules to avoid real-time bycatch hotspots (Pascoe et al., 2010; Alfaro-Shigueto et al., 2012; Dunn et al., 2014; Keefe et al., 2014; Little et al. 2015; Gilman et al. 2006, 2019; Somers et al., 2019; Fader et al., 2021a). Many approaches to mitigating the production and adverse effects of derelict (abandoned, lost and discarded) fishing gear, such as zoning to separate passive and mobile gear sectors, marking gear to increase visibility, using less-durable and biodegradable materials for fishing gear components, prohibiting the use of hazardous materials in gear components, and disabling or removing derelict gear (MacMullen et al., 2003; Huntington, 2017; He and Suuronen, 2018), are similarly applicable across gear types and taxa. Approaches to bycatch offsets, where residual bycatch mortalities that were not avoided and minimized are offset by obtaining an equivalent gain (no net loss/bycatch-neutral), or a more-than-equivalent net gain

(Milner-Gulland et al. 2018), likewise are applicable across fishing methods and species. Rewards, penalties, and a combination of these two approaches can be used as the consequence of compliance / non-compliance with a bycatch measure or for meeting / exceeding a bycatch performance standard (Gjertsen et al. 2010; Pascoe et al. 2010; Squires et al., 2021; Booth et al., 2021).

Appendix 1 includes cross-gear and -taxa methods, but only those that are specific to mitigating the catch risk and mortality of bycatch. For example, a record for bycatch quotas is included – which is a type of output control and is an approach used to meet bycatch management objectives (see Supplemental Material Section S2 of Gilman et al., 2021a), but not the broader approach of output controls, and not approaches within this category that are not specifically implemented to manage bycatch, such as TACs for target species. Similarly, a record is included in Appendix 1 for limiting soak duration and mainline length, which may reduce catch and at-vessel mortality rates for some species of longline bycatch (Ward et al., 2004; Gilman et al., 2006; Werner et al., 2006; Campana et al., 2009; FAO, 2010; Ferreira et al., 2011; Epperly et al., 2012; Acevedo et al., 2013; Baez et al., 2016; Poisson et al., 2017; NMFS, 2020; Fader et al., 2021b), but not the higher-level category of input controls or approaches within this category such as limited entry, buybacks or limits on the number of sets or trips, which may contribute to reducing bycatch but are not typically implemented to achieve bycatch management objectives.

Stakeholders also considered in which of the four tiers of a sequential mitigation hierarchy that a bycatch mitigation method falls. Problematic bycatch can be managed through a mitigation hierarchy sequence of:

1. Avoidance of the risk of capture;
2. Minimization of the risk of capture;
3. Remediation (also referred to as restoration and on-site rehabilitation) by reducing the probability of one or more of the components of post-capture mortality (pre-catch, retained catch, dead discards, ghost-fishing, post-release and collateral mortalities, defined below); and
4. Compensation or offsetting residual bycatch mortalities that were not avoided, minimized and remediated.

Measures to avoid unwanted bycatch can be defined as those that completely prevent one or more extrinsic factors that influence capture risk, referred to as susceptibility or catchability attributes, such as areal overlap, encounterability and selectivity. For example, area-based management tools, ranging from static and permanent no-take marine protected areas to temporally- and spatially-dynamic closures, might enable avoiding bycatch risk of a vulnerable species by eliminating areal or temporal overlap between vessels and a species' distribution.

Methods to reduce bycatch can be categorized as: (1) input controls on effort and output controls on catch levels or rates that indirectly also reduce fishing effort, and (2) measures that involve changes in fishing methods and gear designs that reduce areal overlap, reduce encounterability or increase selectivity to reduce bycatch rates. Limited entry and buyback programs that reduce fishing capacity are examples of bycatch minimization approaches. Area-based management tools that reduce (but do not eliminate) areal or temporal overlap are another example. Changes in gear designs and fishing methods that reduce bycatch rates can be categorized according to their mechanism for reducing catch risk, such as by (FAO 2010; Hall et al., 2017):

- Reducing temporal and areal overlap;

- Reducing depth overlap (e.g., moving shallowest hooks deeper to reduce vertical overlap with epipelagic sharks and marine turtles);
- Increasing selectivity due to morphological characteristics (e.g., organism's mouth dimensions may reduce the probability of ingesting a wider hook);
- Increasing selectivity by increasing the probability of escapement (e.g., using monofilament instead of wire leaders increases shark escapement);
- Reducing gear detection (camouflaged gear, dyed bait);
- Increasing gear detection (e.g., pingers, illumination);
- Shielding the gear to limit access (e.g., streamer *tori* lines, underwater setting devices, devices that cover the hook during the set);
- Reducing the duration of bycatch risk, for example, by reducing the gear soak time, and by increasing longline baited hook sink rates;
- Repelling predators (e.g., acoustic, electrical, chemical, magnetic, rare earth electropositive metals); and
- Reducing attractiveness of the gear (bait type, artificial bait).

The third step in the bycatch mitigation hierarchy is to increase the probability of post-capture survival. For example, for species susceptible to capture by ingesting a hook, the use of circle-shaped hooks can increase the probability of pre-catch, at-vessel and post-release survival relative to J-shaped hooks. Bans on shark finning, where fins are retained and the remaining carcass is discarded, might reduce retention of sharks lacking market value other than for the fins, which in turn might increase post-capture survival. However, for species that are retained for their meat and other products, finning bans may not affect fishing mortality rates. Retention bans are in place for some at-risk species (e.g., oceanic whitetip sharks in Pacific Ocean tuna fisheries, IATTC 2011b; WCPFC 2019). Retention bans have been documented to increase post-capture survival in some fisheries (Gilman et al. 2016), but may not be effective under certain legal and regulatory frameworks (Tolotti et al. 2015; Ward-Paige 2017). Handling and release methods and gear remaining attached also affect the probability of post-release survival. Methods to mitigate the risk or producing derelict fishing gear will reduce ghost fishing mortalities.

Finally, the fourth step is to offset residual bycatch that could not be avoided or minimized, discussed in Section 7 on goals and objectives. Three general approaches to offsetting biodiversity losses are: (1) direct offsets, where the entity responsible for a biodiversity loss directly implements compensatory activities (e.g., address a threat at a marine turtle nesting colony to offset fishery removals); (2) banking, where restored, enhanced, created and in rare cases preserved biodiversity units are quantified as credits that can be debited to provide compensation in advance of authorized impacts of similar biodiversity units; and (3) offset funding, where the entity responsible for the biodiversity loss pays a management authority, environmental non-governmental organization or other body to fund conservation activities (Gilman et al., 2021a). However, regardless of the mechanism for delivering the offset, regardless of who pays and who implements the activity, the activities to achieve the equivalent or gain in biodiversity are the same. Compensatory fisheries bycatch mitigation is a form of biodiversity offset where bycatch fishing mortality is mitigated through actions that address other conservation activities that, in theory, would not otherwise have been implemented. A 'polluter pays' system that requires individual vessels or a fishery to pay a set price as a levy (tax) could be used to raise funds for interventions that offset bycatch mortalities. The extent of a tax could be adjusted based on the species, fate (retained or released), reproductive value, life status (alive, dead) and predictors of post-release survival if released alive. Or, offsets could be funded through a voluntary 'bycatch tax'. Bycatch offsets can be achieved through paying for conservation activities that address other anthropogenic threats to an affected population or species. For instance, a fishery could pay to support activities that mitigate bycatch in other fishing fleets, which could be either or both on-site and off-site, and either or both in-kind (mitigating bycatch of the same populations, age classes, sex ratio) and out-of-kind. A fishery could offset seabird bycatch by eradicating invasive rodents at a nesting colony. For example, while not a 'bycatch tax' paid by the catch sector, some participating tuna canning companies of the International Seafood Sustainability Foundation voluntarily contribute US$1/ton of albacore tuna that they purchase from pelagic longline fisheries, totaling about US$100,000 per year, which is disbursed as grants by The Ocean Foundation to support marine turtle conservation projects. Compensatory mitigation, including mitigation banking, a longstanding practice in wetlands management, could also be applied to fisheries bycatch. However, see Gilman et al. (2021a) for a review of sources of risk may prevent compensatory activities from successfully offsetting residual bycatch impacts.

The bycatch mitigation methods that are currently in use, either due to voluntary industry practices or the contemporary fisheries management framework, identified when benchmarking contemporary fishing practices and the bycatch management framework, were included in this short list.

An assessment of data quality also contributed to determining which bycatch mitigation methods are feasible. For example, a rich time series of observer and EM data and robust surveillance system are required to support dynamic spatial management tools, while both data-limited and data-rich fisheries as well as those with robust and limited surveillance programs could implement static area-based management tools.

Some mitigation methods may be excluded that require monitoring and surveillance approaches for effective compliance monitoring that are not perceived as being feasible to develop within the adopted timeframe for achievement of the objectives. Bycatch mitigation methods that pose a risk of injuring vulnerable bycatch species (e.g., fish and vegetable oil slicks, lasers, acoustic harassment devices) were excluded.

While not implemented here, participants may also decide to exclude methods that do not meet a threshold level of evidence of bycatch mitigation efficacy, such as cetacean depredation and bycatch responses to acoustic-harassment devices and pyrotechnics (Tixier et al. 2021) and escapement rate response to weak hooks (see Section S1 in Gilman et al., 2021a). Conversely, despite having a low evidence hierarchy tier, participants may decide to retain a mitigation method as a precautionary measure if more certain approaches are unavailable. Participants may also agree to exclude certain bycatch mitigation methods because one or more stakeholder group strongly objects to its inclusion, where other options with broader support are available to meet objectives.

Table 3 identifies the subset of bycatch mitigation methods from the exhaustive database of Appendix 1 that the participants excluded from consideration for inclusion in their initial bycatch management strategy, and the rationale for exclusion.

Table 3. Bycatch mitigation methods that were excluded from consideration for inclusion in an initial integrated bycatch management strategy, and the rationale for their exclusion. Bycatch mitigation methods that pose a risk of injuring vulnerable bycatch species (e.g., fish and vegetable oil slicks, lasers, acoustic harassment devices, WPRFMC 2018) were also excluded but are not listed in the table.

Method	Rationale for elimination
Inter-taxa	
Bycatch limit	Not feasible given current monitoring system - but consider in the future revising the current objectives, which are defined by taxa-specific rates, to vessel-based or fleet-based bycatch quotas, if/when the monitoring rate increases to enable robust fleetwide species-specific extrapolations if employing fleet-based quotas, or otherwise obtain 100% monitoring if employing vessel-based quotas.
Restrict fishing at shallow submerged features	Too high a cost to commercial viability, based on input from the catch sector. If selected, would need a database of shallow (e.g., summit depth of <500 m) submerged seamounts in the region, available from SPC, and a rule on distance from the seamount that sets can occur.
Cetaceans	
Weak hook	Too high a risk of economic cost, and lack of evidence of efficacy for a conservation benefit to odontocetes (see Supp. Mat. of Gilman et al., 2021b).
Hookless mainline sections, hookless (dummy) sets	Too high a risk of economic cost, and lack of evidence of efficacy
Set geometry, multiple short sets	Practicality cost is too high
Encase catch (to attempt to reduce cetacean depredation and catchability)	Lack of commercially available equipment. Too high a risk of multispecies conflicts - could increase the pre-catch and haulback fishing mortality of vulnerable species (including small odontocetes).
Marine turtles	
Deeper (hooks fish >100 m) daytime fishing	Too high an economic cost. Gear currently fishes both at night and day, and the depth range of baited hooks is designed to maximize vertical overlap with target species. Fishing deeper poses too high a risk of reducing target species catch rates, and changing to only having gear fish during the daytime would result in a substsantial reduction in fishing effort.
Light emitting devices that have wavelengths and a flicker rate that reduce detection by marine turtles	Ligthsticks are not used. Adoption of a ban on lightstick use would eliminate the relevance of this measure, and the degree of evidence of taxa- and species-specific catch rate responses to different wavelengths, flicker rates and other characteristics of alternative lightsticks is relatively weak.
Seabirds	
Night setting (and shallow-set fishing)	Too high a commercial viability cost, given current practices for soak duration. Changing from the current medium-depth fishing strategy to shallow-set would place a larger proportion of baited hooks at shallower depths, increasing the catchability of threatened epipelagic species, and this multispecies conflict is deemed too high a cost.

Method	Rationale for elimination
Hook shielding devices	Too high economic and practicality costs, and concern over crew safety risks. E.g., use of a hookpod would require a substantial reduction in the hook setting rate, resulting in a large reduction in hooks deployed per set.
Side setting	Too large a change to deck designs and fishing operations.
Underwater setting devices	Available underwater setting devices are unreliable, expensive, limited commercial availability, too large a change to fishing operations, and overall are relatively impractical.
Blue-dyed and thawed bait	Given the use of forage fish species in this fishery, the efficacy of blue-dyed fish bait at reducing seabird catch rates is relatively low.
Towed buoy	Prefer the more effective tori lines over towed buoys.
Bait casting machine / no setting hooks into propeller turbulence	Crew avoid setting hooks into the prop turbulence as this increases bait loss. The cost for this equipment is too high, and is not needed.
Fully thawed fish bait and partially thawed squid bait	Too high an economic cost. Fully thawed fish bait has a higher loss rate than partially-thawed bait.
Sharks	
Repellants (e.g., rare earth electropositive metals, chemical/olfactory, electrical, magnetic)	Low evidence of efficacy, not commercially available, expensive.
Rays	
See 'deeper daytime fishing'	See rationale above under marine turtles.

9. RANKED BYCATCH MITIGATION METHODS

Eric Gilman and Tom Evans ranked the shortlisted bycatch mitigation measures. When ranking, it is important to recognize that certain combinations of mitigation methods may be optimal to meet taxa-specific objectives, and that there are interacting effects of some combinations of variables.

The ranking considered the measures' categorizations in a sequential bycatch mitigation hierarchy. However, participants were instructed to not be restricted to following the sequential hierarchy because, in addition to best overall conservation outcomes, resource management decision-making is also guided by social, economic and governance considerations. Therefore, stakeholders also ranked mitigation methods based on:

(1) How the mitigation method contributes to meeting objectives for mitigating catch and mortality rates of vulnerable bycatch species;
(2) Whether the method meets objectives on acceptable cross-taxa conflicts;
(3) Whether the method meets objectives on acceptable effects on practicality, safety and economic viability; and
(4) The enforceability of the method given the capacity of the Vanuatu fisheries management system and voluntary industry practices to conduct compliance monitoring and the effect of crew behavior on performance of the method.

For example, to assess the relative economic viability of alternative seabird bycatch branchline weighting designs, Gilman et al. (2020) evaluated the initial outlay cost and ongoing cost for replacement of alternative pelagic longline branchline weights, and the effect of alternative weights on replacement rates of other gear component. The assessment also accounted for effects on fishing effort due to the effect of alternative weights on hook setting and retrieval rates, and on the number of branchlines that could be stored in a bin, which both affect the number of hooks deployed per set. Finally, the study also assessed the effect of different weight types on target species catch rates.

For fisheries with limited monitoring and surveillance capacity, bycatch mitigation methods whose performance is strongly affected by crew behavior (e.g., blue-dyed bait, tori line) will be ranked low against the compliance monitoring criterion. Methods that do not rely on crew behavior during fishing, such as methods for which compliance can be determined through dockside inspection (e.g., hook type, branchline weighting design, leader material), will be ranked high, while methods that are affected by crew behavior but can be confirmed without observers and EM (e.g., static area-based management tools input controls on number and time-of-day of fishing operations can be monitored with a satellite-based vessel monitoring system) will be ranked as intermediate.

There is limited or no quantitative information available for most bycatch mitigation methods on their practicality, safety and economic costs. For some bycatch mitigation methods, assessments against these criteria will be highly variable by individual fishery. For example, the effect of a change in hook minimum width on economic viability would depend on: variability in the length frequency distribution of a species that overlaps with a fishery, the difference between the widths of the conventional and new hook, and the difference in the hook widths relative to the species' range of mouth sizes (Gilman et al. 2018). Similarly, outcomes of assessments of the relative efficacy at meeting objectives and enforceability will vary substantially by individual fishery. Therefore, for these criteria, the rankings require knowledge and expertise both with the individual fishery and the candidate bycatch mitigation methods.

Appendix 2 contains an example of an expert survey approach that was used to rank seabird bycatch mitigation methods for relative practicality, safety and economic viability. This form was adapted and expanded for the integrated, multi-taxa planning for this bycatch management plan. Each of the short-listed bycatch mitigation methods listed in Appendix 1 were ranked on a scale of 1-10, with 1 being worst, 10 best, against the criteria identified in the bullet list, above. The results of the ranking of the shortlisted mitigation methods are presented in Appendix 3.

10. BYCATCH MANAGEMENT STRATEGY EVALUATION

Participants conducted management strategy evaluation (MSE) to simulate effects of three alternative suites of fisheries bycatch management measures to assess their predicted efficacy against objectives. A qualitative MSE approach suitable for use at the individual fishery scale was employed. Each of the three alternative strategies included several mitigation methods covering multiple taxa, and were assessed qualitatively by the participants to predict how each would perform towards meeting the objectives for ecological, commercial viability, and multispecies conflict outcomes. Strategy 1 was the status quo, including only currently employed bycatch mitigation measures. Strategy 2 included bycatch mitigation methods for each taxonomic group beyond the status quo that individually would cause only minor commercial viability costs (score of ≥4 for criterion cost to commercial viability). Strategy 3 included additional bycatch mitigation methods for each taxonomic group beyond the status quo that were predicted to be most effective at meeting each vulnerable bycatch objective. The bycatch mitigation measures selected for each strategy were as follows:

Integrated bycatch management strategy 1 – status quo

- Handling and release best practices
- Mitigate production and adverse effects of ALDFG
- Retention ban – EPO: oceanic whitetip sharks, mobulid rays, WCPO: oceanic whitetip and silky sharks, mobulid rays
- Circle hooks, wider than J-shaped hooks
- Forage fish bait, no live bait
- Ban lightsticks
- Single baited hooks
- Tori line
- Monofilament leaders
- Ban shark lines
- Minimum branchline length
- Ban shark finning

Integrated bycatch management strategy 2 – minimal cost to commercial viability

- All Strategy 1 measures
- Retention ban – oceanic whitetip and silky sharks and all rays (all fishing grounds)
- Retention limit – for sharks not subject to a retention ban and with relatively high haulback and post-release survival rates
- Move-on rules and fleet communication
- Minimum depth of shallowest hook
- Branchline longer than floatline (for first and last branchlines attached between floats)
- Branchline weighting design (conventional lead-centered swivel or sliding lead)
- Bird curtain during haulback (pending evaluation of seabird haulback catch rates and levels)
- Minimize deck lighting during night setting
- Bait hooked in the head or tail
- Ban shark lazy line

Integrated bycatch management strategy 3 – high evidence for meeting vulnerable bycatch mitigation objectives

- All Strategy 1 measures
- Retention ban – all elasmobranchs (all fishing grounds)
- Move-on rules and fleet communication
- Soak duration / mainline length limits
- Offset (levies and rewards)
- Static area-based management tools
- Acoustic masking vessels
- Wider hook
- Minimum depth of shallowest hook
- Branchline longer than floatline (for first and last branchlines attached between floats)
- Branchline weighting design (conventional lead-centered swivel or sliding lead)
- Bird curtain during haulback (pending evaluation of seabird haulback catch rates and levels)
- Ban offal and spent bait discharges during setting and hauling
- Minimize deck lighting during night setting

- Branchline length < distance between coiler and stern (pending evaluation of seabird haulback catch rates and levels)
- Bait-swim bladder punctured/species without swim bladders
- Bait hooked in the head or tail
- Ban shark lazy line

Then, the participants qualitatively predicted how each of the three strategies would meet each objective. The results of the qualitative MSE are presented in Figure 3 using a radar plot. The MSE results identify the tradeoffs amongst the objectives of each alternative bycatch management strategy, information used by stakeholders to select the framework with the most preferable tradeoffs.

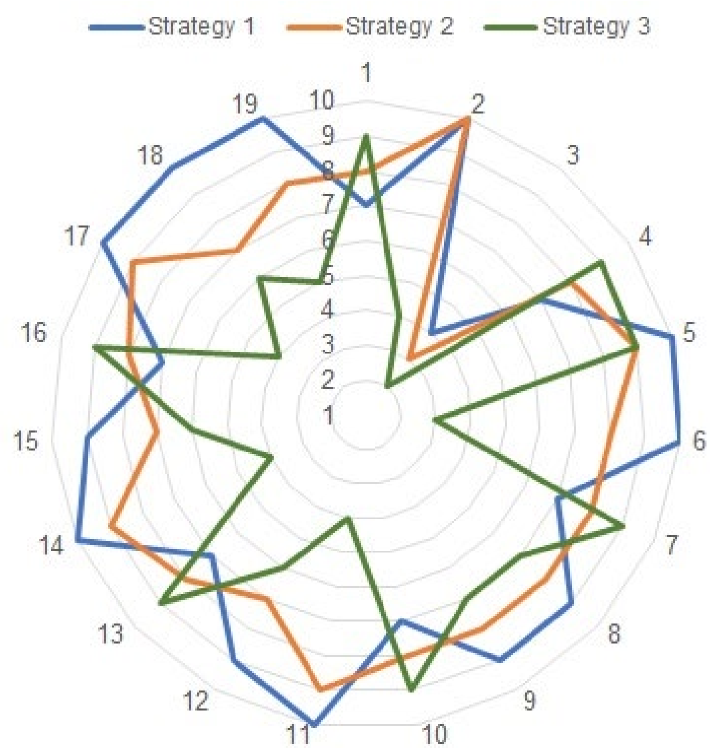

Figure 3. Management strategy evaluation of three alternative integrated bycatch management strategies for the Tunago-Thai Union fishery. Each strategy was assessed against 19 objectives (see key below) on a scale of 1 to 10, where 1 indicates that the strategy is highly unlikely and 10 is highly likely to meet the objective.

Key to objectives in Figure 3:

Objective	Objective
1	Seabirds - cap at 0.45/1000 hooks
2	Seabirds - no multispecies conflicts
3	Seabirds - minor practicality and safety costs, no reduction in catch rates of marketable species
4	Marine mammals - cap at 2/235 sets
5	Marine mammals - minor costs from multispecies conflicts
6	Marine mammals - minor practicality and safety costs

7	Mesopelagic sharks - cap at 0.6/1000 hooks
8	Mesopelagic sharks - minor costs from multispecies conflicts
9	Mesopelagic sharks - minor practicality and safety costs
10	Marine turtles - cap at 0.003/1000 hooks
11	Marine turtles - max 10% increase in species-specific elasmobranch catch rate, no cost to marine mammals or seabirds
12	Marine turtles - minor practicality and safety costs
13	Epipelagic sharks cap at 0.27/1000 hooks, pelagic stingray cap at 1.9/1000 hooks
14	Epipelagic sharks and pelagic stingray - max 10% increase in species-specific elasmobranch catch rate, no cost to marine mammals or seabirds
15	Epipelagic sharks and pelagic stingray - minor practicality and safety costs
16	WCNPO striped marlin - cap at 0.36/1000 hooks
17	WCNPO striped marlin - max 10% increase in species-specific elasmobranch catch rate, no cost to marine mammals or seabirds
18	WCNPO striped marlin - minor practicality and safety costs
19	The effect of combined mitigation measures to manage marine mammal, marine turtle, elasmobranch and striped marlin bycatch can result in a reduction in catch rates of the number of combined retained species per 1000 hooks of up to 1.5%

The participants selected management strategy 2 as the preferred option. Participants used the suite of bycatch mitigation methods in adopted management strategy 2 to then develop and adopt a 2022 bycatch management workplan that identifies their agreed objectives, selected bycatch mitigation measures and agreed improvements to other components of the fisheries management framework of relevance to achieving bycatch-related objectives. The workplan is in Section 12.

A more robust MSE approach could be employed to develop future versions of the bycatch management strategy. Some MSE approaches have been applied to individual fisheries and used expert opinion and stakeholder consultation (Arlidge et al. 2020; Booth et al. 2020) and quantitative, model-based approaches (Tuck 2011; Smith et al. 2021). Others have been applied to regional fisheries using model-based approaches (Harley et al. 2015; Harley and Pilling 2016). Model-based MSE approaches includes operating models of the biological components of the system and of the fishery, estimates of the uncertainty of each of the terms of the operating models, and an implementation model of the application of the fisheries management framework.

A qualitative but more systematic MSE approach could be conducted. For each alternative shortlisted individual and combinations of bycatch mitigation methods, available evidence of effect sizes could be compiled so that methods that enable achieving the desired effect size would be possible to identify, to determine which methods would meet each vulnerable bycatch objective defined in Section 7. For each taxa-specific suite of mitigation methods defined in this initial step, the effect that each suite would have on catch and mortality of other vulnerable taxa could be simulated, enabling determining whether the suite meets objectives on acceptable multispecies conflicts defined in Section 7. Then, in a third step, the suites of bycatch mitigation methods that best achieve both objectives for mitigating catch and mortality of vulnerable bycatch and objectives on acceptable multispecies conflicts, those that also meet or best meet objectives on costs to commercial viability (economic costs, practicality costs, safety costs) could be identified. This could be considered for inclusion in a future version of the bycatch management workplan.

11. ADAPTIVE MANAGEMENT

11.1. Performance Assessments

Participants periodically adapt the bycatch management plan and bycatch management framework. Stakeholders continuously monitor the bycatch management framework by conducting regularly-scheduled, impartial (third or otherwise second-party) performance assessments to determine whether the system is achieving objectives and scheduled milestones, and adapt the bycatch management framework as needed.

11.2. Changes in Management System, Fishery, Ecological Risks

Amendments to the bycatch management framework may also be warranted when there are changes to the fisheries management framework. For instance, RFMOs' adoption of new or amended measures and new or amended Client Action Plans to address conditions of certification against MSC's fisheries standard may trigger updates to the bycatch management plan. Amendments may be needed if there are changes in fishing practices (gear design, fishing methods); changes in bycatch rates, levels and composition, including changes to sex ratios and age classes of vulnerable bycatch; new information from monitoring programs, and results from updated or new ecological risk assessments. Adaptations may also be warranted based on improved evidence derived from primary and synthesis research, and when new bycatch mitigation methods become available. Amendments may be required if stakeholders change their overarching objectives.

Depending on the amendments made to the bycatch management plan, government stakeholders might adopt or amend the legal and regulatory framework and modify fishing license agreements. Stakeholders might adopt new actions that require government participants to improve broad aspects of the fisheries management framework, including monitoring, surveillance and enforcement programs. Amendments to the bycatch management plan may require industry participants to adopt or adapt fishing company policies, industry codes of practice, sustainable seafood sourcing policies and product specs.

12. BYCATCH MANAGEMENT WORKPLAN - 2022

This section defines the integrated bycatch management workplan for calendar year 2022 for the Tunago-Thai Union FIP. For each activity, the management plan defines: measurable milestones, a schedule for completion of each milestone, the implementation lead, and other contributors. A budget is not included, which will be developed and managed separately by the FIP lead Key Traceability.

Improvements to the fisheries management framework cover monitoring, control, surveillance and enforcement systems required to implement the selected bycatch mitigation methods and to conduct performance assessments. This may include voluntary industry measures (catch sector company policies, industry code of practice, buyer seafood sourcing policies and product specs) in addition to improvements to the Vanuatu, WCPFC and IATTC management frameworks.

In addition to defining actions and milestones to achieve objectives, the workplan also has a tactical component that details the process for implementation of the bycatch management actions. Discussed previously, the workplan also defines the process for independent performance assessments, which might be made public and contain evidence of progress, such as is required for independent audits of FIPs and for annual surveillance audits of MSC certified fisheries.

Section 12.1 covers activities that implement adopted bycatch mitigation measures of management strategy 1 (Section 10). Section 12.2 contains activities related to improvements in the management system. And, activities in Section 12.3. are on performance assessments, and adaption of the plan.

12.1. Bycatch Management - Mitigation Measures

Activity 1
Title: Implement the bycatch mitigation methods of the version 1 integrated bycatch management strategy.
Activity description: The following bycatch mitigation methods are to be implemented during 2022: Existing measures to be continued and expanded as described. Thai Union and Vanuatu Fisheries Department will determine which measures will be adopted as binding government requirements vs. voluntary industry policies.

- **1.1. Handling and release best practices**: Define equipment that must be onboard each vessel, and methods to be employed to handle and release seabirds, marine turtles, sharks, rays and whales.
- **1.2. Mitigate production and adverse effects of ALDFG:** Develop and implement MARPOL Annex V garbage management plans. Implement FAO guidelines on gear marking to identify ownership. Develop and implement protocols for reporting lost gear.
- **1.3. Retention ban – EPO: oceanic whitetip sharks, mobulid rays, WCPO: oceanic whitetip and silky sharks, mobulid rays**: Self-explanatory. Combine with handling and release prescribed methods to maximize probability of post-release survival.
- **1.4. Circle hooks, wider than J-shaped hooks**: Self-explanatory. Continue to use current size of circle hooks.
- **1.5. Forage fish bait, no live bait**: Self-explanatory.
- **1.6. Ban lightsticks**: Self-explanatory.
- **1.7. Single baited hooks**: Self-explanatory, and see below on location for baiting.
- **1.8. Tori line**: Confirm the design is in compliance with the IATTC and WCPFC minimum standards.
- **1.9. Monofilament leaders**: Self-explanatory.
- **1.10. Ban shark lines**: Self-explanatory.
- **1.11. Minimum branchline length**: Continue to use branchlines that are a minimum of 20 m in length.
- **1.12. Ban shark finning**: Retained sharks must include the carcass with fins naturally attached.

New measures:

- **1.13. Retention ban – oceanic whitetip and silky sharks and all rays (all fishing grounds**): Expand the retention ban as described.
- **1.14. Retention limit – for sharks not subject to a retention ban and with relatively high haulback and post-release survival rates**: Following the completion of Activity 2, define vessel-based, trip-based and/or set-based species-specific retention limits, for shark species with relatively high haulback survival rates as well as high predicted post-release survival rates.

- **1.15. Move-on rules**: Define agreed protocols for either or both distance moved and time elapsed before making a subsequent set following a set with a threshold catch rate or level by species or taxonomic group.
- **1.16. Fleet communication**: Develop a one-fleet communication program for vessels to share information real-time on bycatch and depredation hotspots so other vessels can avoids these areas.
- **1.17. Minimum depth of shallowest hook**: Either require that (1) branchlines be attached at least 65 m from floatlines, and maintain status quo for floatlines and branchline lengths (floatlines ≥25m, branchlines ≥20m), or (2) require branchlines be attached at least 50 m from floatlines, floatlines ≥25m, branchlines ≥26m.
- **1.18. Branchline longer than floatline (for first and last branchlines attached between floats)**: Self-explanatory.
- **1.19. Branchline weighting design (conventional lead-centered swivel or sliding lead)**: In the southern hemisphere, adopt one of the WCPFC seabird CMM branchline weighting design options. For the northern hemisphere, require a minimum of 40 g within 0.5 m of the hook. Vessels may opt to use conventional lead-centered swivels or sliding weights. Conduct a commercial demonstration of sliding weights.
- **1.20. Bird curtain during haulback (pending evaluation of seabird haulback catch rates and levels)**: Pending results of Activity 2, if seabird bycatch rates and levels are determined to be problematic during the gear haulback, then require deployment of a bird curtain during the haul in areas where the tuna RFMOs require seabird bycatch mitigation methods to be employed.
- **1.21. Minimize deck lighting during night setting**: Modify deck lighting to avoid and minimize coverage of areas where baited hooks are available to seabirds, but maintaining safe deck lighting for crew operations.
- **1.22. Bait hooked in the head or tail**: Do not hook baits in the center, only in the tail or head, in areas where seabird bycatch measures are required by the tuna RFMOs.
- **1.23. Ban shark lazy line**: Prohibit attaching a line to the stern of the vessel where crew temporarily attach sharks and other catch that will later be removed and discarded.

Milestone: (1) Determine which measures are to be required via Vanuatu government vs. by Thai Union as industry policy. Fleet communication will be a voluntary industry program. (2) Through available compliance monitoring approaches, including dockside monitoring, human observer data, EM data, and VMS data, assess compliance with each bycatch mitigation method. (3) Establish shark retention limits and definitions (vessel-based by year, trip and/or set) for species meeting the defined criteria. (4) Establish species- or taxonomic group-specific move-on rules. (5) Establish voluntary industry fleet communication program. (6) Select gear design for minimum depth of shallowest hook, deploy TDRs to measure the fishing depth of shallowest hooks in a basket (between 2 floats) to confirm that the hook is fishing at 80 m or deeper. (7) Conduct a commercial demonstration of sliding weights.

Schedule: Milestone 1: 1 May 2022. Milestone 2: Continuous, during 2022, for each trip. Milestone 3: 1 August 2022. Milestones 4 and 5: 1 June 2022. Milestone 6: 1 August 2022. Milestone 7: before the end of 2022.

Lead: Vanuatu Fisheries Department, Thai Union, Tunago

Contributors: Key Traceability, TNC, Eric Gilman

12.2. Fisheries Management Framework – Monitoring, Control, Surveillance and Enforcement Improvements

Activity 2

Title: From EM data analysis, improved information on haulback condition and compliance with pre-2022 workplan bycatch management measures, and plan for improved ETP information.
Activity description: Analyze available EM data to obtain more certain estimates of shark species-specific haulback survival rates and fate, and determine compliance with bycatch mitigation measures in place prior to adoption of this 2022 workplan. Plan for 2023 analyses of EM data for more certain estimates of catch rates, haulback condition and fate of all vulnerable species (elasmobranchs, marine turtles, seabirds, marine mammals, striped marlin, Pacific bluefin tuna).
Milestone: (1) Report with updated information on haulback survival rates of individual species of sharks, and documenting compliance with bycatch management measures that were in place when the EM data were collected. (2) Report planning 2023 analyses of EM data to estimate catch rates, haulback condition, and fate of vulnerable species, and identification of needed changes to the objectives and bycatch management strategy to address the new information.
Schedule: Complete EM analyses: 1 May 2022. Complete milestones 1 and 2: 1 July 2022
Lead: Eric Gilman, Tom Evans, Iain Pollard
Contributors: Vanuatu Fisheries Department, Tunago, Satlink, Thai Union, TNC

Activity 3
Title: Improved information on gear designs and materials and fishing methods from a dockside inventory and analysis of EM data.
Activity description: Conduct a dockside inventory of Tunago fishing vessels and analyze available EM data to fill gaps or otherwise obtain more robust estimates of gear designs and fishing methods. Depending on Covid international travel restrictions, an in-country technician may be contracted to implement the dockside inventory. The variables summarized in Section 5 will be confirmed. And, the gaps in information identified in column 1 of Table 1 in Appendix 1 would potentially be filled through this activity. This includes filling gaps in information on:

- Equipment onboard for handling and release of ETP species
- Current methods for mitigating the production of ALDFG (e.g., frequency of radio buoys incorporated into the mainline, Marpol Annex V Garbage Management Plan, reporting lost gear, no hooks in discarded spent bait, marking gear to increase visibility and marking gear to identify ownership) and adverse effects (e.g., use of non-toxic materials where feasible)
- Whether the branchline length < distance between crew conducting branchline coiling and the vessel stern
- Bait thaw status when setting
- Bait hooking position (head, tail, center)

Milestone: (1) A dockside inventory form will be developed and used to standardize data collection on each vessel. (2) Report with updated information on the contemporary fishing methods and gear used by the Tunago vessels, identification of needed changes to the bycatch management strategy to address the new information.
Schedule: Complete EM analyses: 1 May 2022. Prepare dockside inventory form by 1 May 2022. Complete dockside inventory: 1 June 2022. Complete milestone 2: 1 July 2022
Lead: Eric Gilman, Tom Evans, Iain Pollard
Contributors: Vanuatu Fisheries Department, Tunago, Satlink, Thai Union, TNC

Activity 4
Title: Confirm available observer monitoring information

Activity description: Determine if there has been any conventional human observer coverage of the Tunago vessels in the past 5 years, and if yes, obtain access to the data and include this in the planned activities that assess EM data.
Milestone: Vanuatu observer program data, if available from the previous 5 years, is obtained and analyzed as part of activities 2 and 3.
Schedule: Determine availability, obtain and process by 1 July 2022
Lead: Tom Evans, Eric Gilman
Contributors: Vanuatu Fisheries Department, Tunago, Thai Union

Activity 5
Title: Human or EM coverage rate for 2022
Activity description: Achieve a minimum of 20% coverage rate of a combination of EM and human observers, with 20% of sets by each of the 10 Tunago vessels monitored, and half of the coverage split between the north and south Pacific.
Milestone: ≥20% coverage rate achieved for calendar year 2022.
Schedule: By end of 2022.
Lead: Thai Union, Vanuatu Fisheries Department
Contributors: Key Traceability, TNC, Tunago

Activity 6
Title: Vanuatu government bycatch control, surveillance and enforcement systems
Activity description: Work with the Vanuatu Fisheries Department to confirm and revise Vanuatu's bycatch-related management measures. Obtain a current Vanuatu license agreement to identify any conditions relevant to bycatch management. Identify surveillance activities – such as number of at-sea boardings, dockside inspections or use of observer or EM data for compliance monitoring purposes. Determine the number of identified infractions, if any, in the past 5 years, for the Tunago fishery, what enforcement actions resulted from the identified infractions, and the outcomes of the enforcement actions.
Milestone: Updated, accurate and current summary of the domestic fisheries management framework.
Schedule: 1 June 2022
Lead: Key Traceability, Vanuatu Fisheries Department
Contributors: Thai Union

Activity 7
Title: Incentives – penalties and rewards
Activity description: Adopt a suite of economic and social incentives, both rewards and penalties, to incentivize Tunago vessel effective implementation of required bycatch mitigation methods. Compliance with required bycatch mitigation methods can be incentivized through a broad range of combinations of penalties and rewards through government fisheries management frameworks as well as through market-based mechanisms.
Milestone: Thai Union and the Vanuatu Fisheries Department adopt voluntary industry and government rewards and penalties, respectively, for compliance and infractions with required bycatch mitigation methods. In addition to financial penalties, requiring more stringent bycatch mitigation methods the following year and increased at-sea EM coverage are additional options.
Schedule: Develop the agreed incentive program by the end of 2022, for implementation beginning in 2023.
Lead: Tom Evans, Eric Gilman
Contributors: Vanuatu Fisheries Department, Tunago, Thai Union, TNC

12.3. Performance Assessments and Adaptive Management

Activity 8
Title: Stakeholder assessment
Activity description: Develop a plan to conduct a stakeholder assessment to determine whether any groups or companies that are not formal participants of the Thai Union FIP should directly participate in further development and implementation of the bycatch management strategy and workplan. This may include secretariat staff of IATTC and WCPFC; companies in the seafood supply chain (intermediaries, processors, exporters and importers, distributors, wholesalers, and end buyers); environmental and social non-governmental organizations; and fisheries scientists.
Milestone: Report documenting plan for conducting the stakeholder assessment, which may result in additional stakeholders being identified that Thai Union and Tunago agree to include in future work to update the bycatch strategy and workplan.
Schedule: Complete milestone by 1 December 2022.
Lead: Tom Evans
Contributors: Vanuatu Fisheries Department, Thai Union, Tunago, TNC, Eric GIlman

Activity 9
Title: SMEs rank alternative bycatch mitigation methods
Activity description: Develop a plan to Identify subject matter experts with extensive knowledge of alternative methods to mitigate the bycatch of threatened species in pelagic longline fisheries, including the relative degree of efficacy at reducing catch and mortality, relative degree of evidence of efficacy, practicality, safety, economic viability, multispecies conflicts, and requirements for compliance monitoring. These experts would review the ranking of the alternative bycatch mitigation methods in version 1 of the bycatch management strategy and recommend any modifications.
Milestone: Report documenting plan for SME ranking.
Schedule: Complete milestone by 1 December 2022.
Lead: Eric Gilman, Tom Evans
Contributors: Vanuatu Fisheries Department, Thai Union, TNC

Activity 10
Title: Performance Assessments
Activity description: Periodic assessments of performance of the bycatch management plan will identify: (1) progress towards achieving goals and objectives; (2) whether milestones have been achieved according to the schedule; (3) modifications to actions or adoption of new actions to address deficits, if any.
Milestone: Performance assessment report.
Schedule: While the fishery is in a FIP, performance assessments will be conducted every 6 months. If certified against the MSC fisheries standard, performance assessments will be conducted annually, prior to each MSC annual surveillance audit.
Lead: Key Traceability
Contributors: MSC fisheries certificate holder, current (December 2021) FIP participants.

Activity 11
Title: Adaptive Management –Integrated Bycatch Management Workplan 2023-2026 and Plan to Update Integrated Bycatch Management Strategy
Activity description: Produce a bycatch management workplan for the period 2023-2026, through to the end date of the initial MSC fisheries certificate. Plan for future updates of the bycatch management strategy.
Milestone: Workplan from January 2023.

Schedule: December 2022.
Lead: Eric Gilman, Tom Evans, Iain Pollard
Contributors: Vanuatu Fisheries Department, Tunago, Thai Union, TNC

13. REFERENCES

Acevedo, D, Báez, JC, García-Barcelona, S, et al (2013) Influencia del tiempo de permanencia del aparejo en el agua sobre la captura accesoria del palangre semi-pelágico. Collect. Vol. Sci. Pap. ICCAT 69:1918-1928

Alfaro-Shigueto J, Mangel JC, Dutton PH, et al (2012) Trading information for conservation: a novel use of radio broadcasting to reduce sea turtle bycatch. Oryx 46:332-339.

Amande M, Chassot E, Chavance P, Murua H, Delgado de Molina A, Bez N (2012) Precision in bycatch estimate: the case of tuna purse-seine fisheries in the Indian Ocean. ICES J Mar Sci 69:1501-1510

Arlidge W, Squires D, Alfaro-Shigueto J, Booth H, Mangel J, Milner-Gulland E (2020) A mitigation hierarchy approach for managing sea turtle captures in small-scale fisheries. Front Mar Sci 7:49. doi: 10.3389/fmars.2020.00049

Babcock E, Pikitch E, Hudson G (2003) *How Much Observer Coverage is Enough to Adequately Estimate Bycatch?* Pew Institute for Ocean Science, Miami, and Oceana, Washington, D.C.

Báez, JC, Crespo, G., Garcia-Barcelona, S., et al (2016) Understanding pelagic stingray (Pteroplatytrygon violacea) by-catch by Spanish longliners in the Mediterranean Sea. Journal of the Marine Biological Association of the United Kingdom 96: 1387-1394.

Booth H, Arlidge W, Squires D, Milner-Gulland E (2021) Bycatch levies could reconcile trade-offs between blue growth and biodiversity conservation. Nat Ecol 5: DOI: 10.1038/s41559-021-01444-4.

Booth H, Squires D, Milner-Gulland E (2020) The mitigation hierarchy for sharks: A risk-based framework for reconciling trade-offs between shark conservation and fisheries objectives. Fish Fish 2:269-289

Bravington M, Burridge C, Toscas P (2003) Design of Observer Program to Monitor Bycatch Species in the Eastern Tuna and Billfish Fishery. Secretary of the Pacific Community, Noumea, New Caledonia

Campana S, Joyce W, Francis M, Manning M (2009) Comparability of blue shark mortality estimates for the Atlantic and Pacific longline fisheries. Marine Ecology Progress Series 396:161-164.

Clarke S, Sato M, Small C et al (2014) Bycatch in Longline Fisheries for Tuna and Tuna-like Species: A Global Review of Status and Mitigation Measures. FAO Fisheries and Aquaculture Technical Paper 588. Food and Agriculture Organization of the United Nations, Rome

CMS (2020) Appendices I and II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS). Convention on the Conservation of Migratory Species of Wild Animals Secretariat, Bonn, Germany.

Davidson L, Krawchuk M, Dulvy N (2015) Why have global shark and ray landings declined: Improved management or overfishing? Fish Fish 17: 438-458

Dunn, D. C., Boustany, A. M., Roberts, J. J., Brazer, E., Sanderson, M., Gardner, B., et al. (2014). Empirical move−on rules to inform fishing strategies: a New England case study. *Fish Fish.* 15, 359–375.

Epperly SP, Watson JW, Foster DG, Shah A (2012) Anatomical hooking location and condition of animals captured with pelagic longlines: The Grand Banks experiments 2002-2003. Bulletin of Marine Science 88:513-527

Fader J, Baird R, Bradford A, Dunn D, Forney K, Read A (2021b) Patterns of depredation in the Hawaii deep-set longline fishery informed by fishery and false killer whale behavior. Ecosphere 12(8).

Fader J, Elliott B, Read A (2021a) The challenges of managing depredation and bycatch of toothed whales in pelagic longline fisheries: Two U.S. case studies. Front Mar Sci 8:618031

FAO (2010) Guidelines to Reduce Sea Turtle Mortality in Fishing Operations. By Gilman, E., Bianchi, G. FAO Technical Guidelines for Responsible Fisheries. ISBN 978-92-106226-5. Food and Agriculture Organization of the United Nations, Rome

FAO (2011) International Guidelines on Bycatch Management and Reduction of Discards. Food and Agriculture Organization of the United Nations, Rome

Ferreira R, Martins H, Bolten A, et al (2011) Influence of environmental and fishery parameters on loggerhead sea turtle by-catch in the longline fishery in the Azores archipelago and implications for conservation. Journal of the Marine Biological Association of the United Kingdom 91:1697-1705

Gillet R (2011) Bycatch in Small-scale Tuna Fisheries: A Global Study. FAO Fisheries and Aquaculture Technical Paper No. 560. Food and Agriculture Organization of the United Nations, Rome

Gilman E, Beverly S, Musyl M, Chaloupka M (2020) Commercial viability of alternative designs placing pelagic longline branchline weights at the hook to reduce seabird bycatch. *Endanger Species Res* 43:223-233

Gilman E, Chaloupka M, Dagorn L et al (2019a) Robbing Peter to pay Paul: Replacing unintended cross-taxa conflicts with intentional tradeoffs by moving from piecemeal to integrated fisheries bycatch management. *Rev Fish Biol Fish* 29:93-123Gilman E, Chaloupka M, Merrifield M, Malsol N, Cook C (2016) Standardized catch and survival rates, and effect of a ban on shark retention, Palau pelagic longline fishery. *Aquat Conserv* 26:1031-1062

Gilman, E., Chaloupka, M., Musyl, M. 2018. Effects of pelagic longline hook size on species- and size-selectivity and survival. *Reviews in Fish Biology and Fisheries* 28: 417-433.

Gilman E, Chaloupka M, Sieben C (2021b) Ecological Risk Assessment for a Data-Limited Tuna Fishery Using an Ensemble of Approaches. Prepared for the Key Traceability Pacific Ocean Tuna Longline Thai Union FIP.

Gilman EL, Dalzell P, Martin S (2006) Fleet communication to abate fisheries bycatch. Marine Policy 30:360-366.

Gilman E, Hall M, Booth H, Chaloupka M, Fennell H, Kaiser M, Kardad D, Milner-Gulland E (2021a) A decision support tool for integrated fisheries bycatch management. Rev Fish Biol Fish.

Gilman E, Kaiser M, Chaloupka M (2019) Do static and dynamic marine protected areas that restrict pelagic fishing achieve ecological objectives? Ecosphere 10: DOI:10.1002/ecs2.2968

Gilman E, Musyl M, Suuronen P, Chaloupka M, Gorgin S, Wilson J, Kuczenski B (2021c) Highest risk abandoned, lost and discarded fishing gear. Scientific Reports DOI: 10.1038/s41598-021-86123-3.

Gilman E, Passfield K, Nakamura K (2014) Performance of regional fisheries management organizations: ecosystem-based governance of bycatch and discards. Fish Fish 15:327-351

Gilman, E, E. Zollett, S. Beverly, H, Nakano, D. Shiode, K. Davis, P. Dalzell, I. Kinan (2006) Reducing sea turtle bycatch in pelagic longline gear. Fish Fish 7:2-23.

Gjertsen H, Hall M, Squires D (2010) Incentives to address bycatch issues. In Allen R, Joseph H, Squires G (Eds). Conservation and Management of Transnational Tuna Fisheries. Wiley-Blackwell Publishing, Hoboken, pp. 225–250.

Good S, Baker G, Gummery M, Votier S, Phillips R (2020) National Plans of Action (NPOAs) for reducing seabird bycatch: Developing best practice for assessing and managing fisheries impacts. Biol Conserv 247:108592

Hall MA, Gilman E, Minami H, Mituhasi T, Carruthers E (2017) Mitigating bycatch in tuna fisheries. Rev Fish Biol Fish 27:881-908

Hall MA, Roman M (2013) Bycatch and Non-tuna Catch in the Tropical Tuna Purse Seine Fisheries of the World. FAO Fisheries and Aquaculture Technical Paper No. 568. Food and Agriculture Organization of the United Nations, Rome

Harley S, Caneco B, Donovan C, Tremblay-Boyer L, Brouwer S (2015) Monte Carlo Simulation Modelling of Possible Measures to Reduce Impacts of Longlining on Oceanic Whitetip and Silky Sharks. WCPFC-SC11-2015/EB-WP-02. Western and Central Pacific Fisheries Commission, Kolonia, Federated States of Micronesia

Harley S, Pilling G (2016) Potential Implications of the Choice of Longline Mitigation Approach Allowed within CMM 2014-05. WCPFC-SC12-2016/EB-WP-06 Rev 1. Western and Central Pacific Fisheries Commission, Kolonia, Federated States of Micronesia

He, P., Suuronen, P (2018) Technologies for the marking of fishing gear to identify gear components entangled on marine animals and to reduce abandoned, lost or otherwise discarded fishing gear. Marine Pollution Bulletin 129: 253-261.

Huntington, T (2017) *Development of a Best Practice Framework for the Management of Fishing Gear. Part 2. Best Practice Framework for the Management of Fishing Gear*. Global Ghost Gear Initiative, World Animal Protection, London.

IATTC (2011a) 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, USA.

IATTC (2011b) Resolution on the Conservation of Oceanic Whitetip Sharks Caught in Association with Fisheries in the Antigua Convention Area. Resolution C-11-10. Inter-American Tropical Tuna Commission, La Jolla, USA

IATTC (2016) Resolution on the Management of Sharks. Resolution C-16-05. Inter-American Tropical Tuna Commission, La Jolla, USA.
Keefe CE, Cadrin SX, Stokesbury KDE (2014) Evaluating effectiveness of time/area closures, quotas/caps, and fleet communications to reduce fisheries bycatch. ICES J Mar Sci 71:1286-1297
Key Traceability (2020a) *ETP Management Strategy for the Pacific Longline Tuna FIP*. Version 1.0. Key Traceability, Portsmouth, UK.
Key Traceability (2020b) Updated Pre-assessment of Pacific Longline Tuna (Thai Union) Fishery against the Marine Stewardship Council Fisheries Standard. Version 4.0. Key Traceability, Portsmouth, UK.
Key Traceability (2020c) Updated Action Plan of the Pacific Longline Tuna (Thai Union) Fishery. Version 2.0. Key Traceability, Portsmouth, UK.
Key Traceability (2021) *Pacific Ocean Tuna – Longline Thai Union Fishery Improvement Project*. FisheryProgress.org FIP record ID number 7651. Available online, https://fisheryprogress.org/fip-profile/pacific-tuna-longline. Key Traceability, Portsmouth, UK.
Lawson T (2006) Scientific Aspects of Observer Programmes for Tuna Fisheries in the Western and Central Pacific Ocean. WCPFC-SC2-2006/ST WP-1. Western and Central Pacific Fisheries Commission, Palikir, Federated States of Micronesia
Lennert-Cody C (2001) Effects of sample size on bycatch estimation using systematic sampling and spatial post-stratification: summary of preliminary results. IOTC Proceedings 4:48-53.
Little A, Needle C, Hilborn R, Holland D, Marshall C (2015) Real-time spatial management approaches to reduce bycatch and discards: experiences from Europe and the United States. Fish Fish 16:576-602
MacMullen, P., Hareide, N., Furevik, D., Larsson, P., Tschernij, V., et al (2003) *A Study to Identify, Quantify and Ameliorate the Impacts of Static Gear Lost at Sea*. FANTARED 2. Sea Fish Industry Authority, Hull, UK.
Milner-Gulland EJ, Garcia S, Arlidge W et al (2018) Translating the terrestrial mitigation hierarchy to marine megafauna by-catch. Fish Fish 19:547-561
NMFS (2020) Taking of Marine Mammals Incidental to Commercial Fishing Operations; Amendment to the Atlantic Pelagic Longline Take Reduction Plan. Federal Register 85: 81168–81175.
Pascoe, S., Innes, J., Holland, D., et al (2010) Use of incentive-based management systems to limit bycatch and discarding. International Review of Environmental and Resource Economics 4: 123-161.
Poisson F, Crespo FA, Ellis JR, et al (2017) Technical mitigation measures for sharks and rays in fisheries for tuna and tuna-like species: turning possibility into reality. Aquatic Living Resources 29
Republic of Vanuatu (2009) Republic of Vanuatu Fisheries Act [CAP 315] Fisheries Regulations Order No. 28 of 2009. Government of the Republic of Vanuatu, Por Vila, Vanuatu.
Republic of Vanuatu (2014) Republic of Vanuatu Fisheries Act No. 10 of 2014. Government of the Republic of Vanuatu, Por Vila, Vanuatu.
Smith J, Tommasi D, Welch H et al (2021) Comparing dynamic and static time-area closures for bycatch mitigation: A management strategy evaluation of a swordfish fishery. Front Mar Sci doi: 10.3389/fmars.2021.630607
Somers, K., Pfeiffer, L., Miller, S., Morrison, W (2019) Using incentives to reduce bycatch and discarding: Results under the west coast catch share program. Coastal Management 46: 1-17.
Squires D, Lent R, Dutton P, Dagorn L, Balance L (2021) Credit systems for bycatch and biodiversity conservation. Front Mar Sci doi: 10.3389/fmars.2021.613279.
Tixier P, Lea M, Hindell M, Welsford D, Maze C, Gourguet S, Arnould J (2021) When large marine predators feed on fisheries catches: Global patterns of the depredation conflict and directions for coexistence. Fish Fish 22:31-53
Tolotti M, Filmalter J, Bach P, Travassos P, Seret B, Dagorn L (2015) Banning is not enough: The complexities of oceanic shark management by tuna regional fisheries management organizations. Glob Ecol Conserv 4:1-7
Tuck G (2011) Are bycatch rates sufficient as the principal fishery performance measure and method of assessment for seabirds? Aquat Conserv 21:412–422
Tunago Fishery Co. (2019) *Shark Conservation Policy*. Tunago Fishery Co.: Kaohsiung, Taiwan.
Vanuatu Fisheries Department (2014) Vanuatu Monitoring, Control, Surveillance (MSC) and Inspection Plan. Fisheries Department, Government of the Republic of Vanuatu, Por Vila, Vanuatu.
Vanuatu Fisheries Department (2015). Vanuatu National Plan of Action for Reducing Incidental Catch on Seabirds in Longline Fisheries 2016-2020. Vanuatu Fisheries Department, Government of the Republic of Vanuatu, Por Vila, Vanuatu.

Vanuatu Fisheries Department (2019) Annual Report to the Commission. Part 1: Information on Fisheries, Research, and Statistics. WCPFC-SC15-AR/CCM-28. Fisheries Department, Government of the Republic of Vanuatu, Por Vila, Vanuatu.

Vanuatu Fisheries Department (2021) Annual Report to the Commission. Part 1: Information on Fisheries, Research, and Statistics. WCPFC-SC17-AR/CCM-28. Fisheries Department, Government of the Republic of Vanuatu, Por Vila, Vanuatu.

Vanuatu Fisheries Department and FFA (2015) Vanuatu National Plan of Action on Sharks (2015-2018). Available online, http://www.fao.org/3/a-az639e.pdf. Vanuatu Fisheries Department, Por Vila, Vanuatu.

Wakefield C, Hesp S, Blight S, Molony B, Newman S, Hall N (2018) Uncertainty associated with total bycatch estimates for rarely-encountered species varies substantially with observer coverage levels: Informing minimum requirements for statutory logbook validation. Mar Policy 95:273-282

Ward P, Myers RA, Blanchard W (2004) Fish lost at sea: the effect of soak time on pelagic longline catches. Fishery Bulletin 102:179-195

Ward-Paige C (2017) A global overview of shark sanctuary regulations and their impact on shark fisheries. Mar Policy 82:87-97

WCPFC (2018) Conservation and Management Measure to Mitigate the Impact of Fishing for Highly Migratory Fish Stocks on Seabirds. CMM 2018-03. Western and Central Pacific Fisheries Commission, Kolonia, Federated States of Micronesia.

WCPFC (2019) Conservation and Management Measure for Sharks. CMM 2019-04. Western and Central Pacific Fisheries Commission, Kolonia, Federated States of Micronesia.

Werner T, Kraus S, Read A, Zollett E (2006) Fishing techniques to reduce the bycatch of threatened marine animals. Marine Technology Society Journal 40:50-68.

Williams, P., Pilling, G., Nicol, S. (2020) Available Data on Cetacean Interactions in the WCPFC Longline and Purse Seine Fisheries. WCPFC-SC16-2020/ST IP-12. Western and Central Pacific Fisheries Commission, Kolonia, Federated States of Micronesia.

WPRFMC (2019) Appendix 5. Fact Sheets on Seabird Bycatch Mitigation Methods for Pelagic Longline Fisheries. Report of the Workshop to Review Seabird Bycatch Mitigation Measures for Hawaii's Pelagic Longline Fisheries. ISBN: 978-1-944827-37-3. September 18-19, 2018. Available online, https://tinyurl.com/seabird-mitig. Western Pacific Regional Fishery Management Council, Honolulu.

APPENDIX 1. Exhaustive Database and Shortlisted Pelagic Longline Bycatch Mitigation Methods

Table 4 contains a summary of bycatch mitigation methods for pelagic longline fisheries, providing a simplified overview of species group-specific effects on bycatch and mortality rates. Bycatch mitigation methods that pose a risk of injuring vulnerable bycatch species (e.g., fish and vegetable oil slicks, lasers, acoustic harassment devices, WPRFMC 2018) were excluded. Most of the included mitigation methods have relatively robust evidence of efficacy. However, some approaches where effects are inconclusive, such as weak hooks (see Section S1 of Gilman et al., 2021a) and move-on rules for cetacean bycatch mitigation, were also included despite lacking strong evidence of efficacy because they are considered worthwhile for the participants consideration as a precautionary measure because more certain approaches are unavailable for this group, and because they are understood to hold promise (Fader et al. 2021a,b; Gilman et al., 2021a; Tixier et al. 2021).

Explained in Section 8, Appendix 1 includes cross-gear and -taxa methods, but only those that are specific to mitigating the catch risk and mortality of bycatch. For example, a record is included for limiting soak duration and mainline length, which may reduce catch and at-vessel mortality rates of longline bycatch (Gilman et al., 2006; Werner et al., 2006; Campana et al., 2009; FAO, 2010; Epperly et al., 2012; Acevedo et al., 2013; Baez et al., 2016; Poisson et al., 2017; NMFS, 2020; Fader et al., 2021b), but not the higher-level category of input controls or approaches within this category such as limited entry, buybacks or limits on the number of sets or trips, which may contribute to reducing bycatch but are not typically implemented to achieve bycatch management objectives.

Records are included for some combinations of methods where interacting effects have been documented. Combinations of methods may maximize mitigation efficacy and enable meeting objectives. Furthermore, there are synergistic, interacting effects of some mitigation methods. For instance, the time-of-day of fishing operations and fishing depth determine encounterability and catch risk for pelagic predators whose vertical distributions vary temporally due to diel vertical migration cycles, time of day of foraging and temporal variability in diving behavior. Interacting effects of hook type, bait type and leader material is an additional example: Hook shape, hook size and bait type can affect anatomical hooking position and therefore affect the ability of some species to escape when monofilament leaders are used, but not when more durable wire and multifilament leader materials are used.

Table 4. High-level overview of bycatch mitigation method options for pelagic longline fisheries, species group-specific effects on bycatch risk and post-capture mortality rate (PCMR) and compliance monitoring requirements (adapted from Gilman et al., 2021a). Methods are sorted into taxonomic groups for which they are typically prescribed as a bycatch mitigation approach, and then by mitigation hierarchy tier. For each method, the first row is catch rate response, and the second row is PCMR response. Commercial use refers to whether the approach is in use, either voluntarily or through a binding measure, in one or more pelagic longline fishery. ▲ = reduces pelagic longline bycatch risk or post-capture mortality rate (PCMR); — = no effect; ▼ = increases bycatch risk or PCMR; ? = inconclusive/unknown; V = response is variable; O = offset bycatch mortalities.

Method	Used by Tunago fishery?	Cet-aceans	Turtles-hard-shelled	Turtles-leather-back	Rays	Sea-birds	Sharks-epi-pelagic	Sharks-meso-pelagic	Tel-eosts	Mitigation hierarchy tier[1]	Com-mercial use?	Observer or EM coverage required for compliance monitoring?
Inter-taxa												
Bycatch limit[2]	N	▲	▲	▲	▲	▲	▲	▲	▲	Avoid-BR	Y	Y
		—	—	—	—	—	—	—	—	NA		
Handling and release best practices (e.g., taxa-specific guides of tuna RFMOs, ISSF, ACAP)	Unknown	—	—	—	—	—	—	—	—	NA	Y	Y
		?	▲	▲	▲	▲	▲	▲	▲	Minimize-PCMR		
Move-on rule	N	▲	▲	▲	?	?	?	?	?	Avoid-BR	Y	Y
		—	—	—	—	—	—	—	—	NA		
Restrict fishing at shallow submerged features	N	▲	▲	▲	?	?	▲	V	V	Avoid-BR	Y	N
		—	—	—	—	—	—	—	—	NA		
Mitigate risk of producing derelict (abandoned, lost or discarded) gear, including, for example, from hazardous materials, and ghost fishing duration and efficiency.[3]	Incompletely known	—	—	—	—	▲	—	—	—	Minimize-BR	Y	Y
		▲	▲	▲	▲	—	▲	▲	▲	Avoid-PCMR, Minimize-PCMR		
Retention ban	Y	—	—	—	—	—	—	—	—	NA	Y	N
		▲	▲	▲	▲	▲	▲	▲	▲	Minimize-PCMR		

Method	Used by Tunago fishery?	Cet-aceans	Turtles-hard-shelled	Turtles-leather-back	Rays	Sea-birds	Sharks-epi-pelagic	Sharks-meso-pelagic	Tel-eosts	Mitigation hierarchy tier[1]	Com-mercial use?	Observer or EM coverage required for compliance monitoring?
Retention limit (individual or fleet-based, market species of sharks, teleosts)	N	— —	— —	— —	— —	— —	— ▲	— ▲	— ▲	NA Minimize-PCMR	Y	N
Soak duration limit	N	▲ ?	▲[8] ▲	▲[8] ▲	▲ ?	— V	▲ ▲	▲ ▲	V ▲	Minimize-BR Minimize-PCMR	Y	N
Offsets: residual bycatch mortalities that were not avoided and minimized are offset by obtaining an equivalent gain (no net loss/bycatch-neutral), or a more-than-equivalent net gain	N	O O	O O	O O	O O	O O	O O	O O	O O	Offset Offset	Y	Y
Area-based management tools (static and dynamic)	N	V —	V —	V —	V —	V —	V —	V —	V —	Avoid-BR NA	Y	Depends on design
Fleet communication	N	▲ —	▲ —	▲ —	▲ —	▲ —	▲ —	▲ —	▲ —	Minimize-PCMR NA	Y	Y
Cetaceans												
Weak hook[2]	N	? ?	— —	— —	— —	— —	▼ ?	▼ ?	V[5] ?	Minimize-BR Minimize-PCMR	Y	Y
Mainline length limit	N	?	?	?	?	?	?	?	?	Minimize-BR	Y	N

Method	Used by Tunago fishery?	Cet-aceans	Turtles-hard-shelled	Turtles-leather-back	Rays	Sea-birds	Sharks-epi-pelagic	Sharks-meso-pelagic	Tel-eosts	Mitigation hierarchy tier[1]	Com-mercial use?	Observer or EM coverage required for compliance monitoring?
		?	?	?	?	?	?	?	?	Minimize-PCMR		
Hookless mainline sections, hookless (dummy) sets	N	? —	? —	? —	? —	? —	? —	? —	? —	Minimize-BR NA	Y	Y
Set geometry, multiple short sets	N	? —	? —	? —	? —	? —	? —	? —	? —	Minimize-BR NA	Y	Y
Encase catch (to attempt to reduce cetacean depredation and catchability)	N	? —	? ?	? ?	? ?	? ?	? ?	? ?	? ?	Minimize-BR NA	Y	Y
Acoustic masking - quieter vessels	N	? —	— —	— —	— —	— —	— —	— —	— —	Minimize-BR NA	?	N
Marine turtles												
Circle hooks required instead of J-shaped hooks of the same width, with no more than 10 degree offset	Y	▲ —	— ▲	▲ ▲	▲ —	— —	▼ ▲	▼ ▲	V ▲	Minimize-BR Minimize-PCMR	Y	N
Wider hook	Y	— ▼	▲ ▲	▲ ▲	▲ —	— —	V —	V —	V —	Minimize-BR Minimize-PCMR	Y	N
Wider circle v. narrower J-shaped hook	Y	▲	▲	▲	▲	▲[6]	▼	▼	V	Minimize-BR	Y	N

Method	Used by Tunago fishery?	Cet-aceans	Turtles-hard-shelled	Turtles-leather-back	Rays	Sea-birds	Sharks-epi-pelagic	Sharks-meso-pelagic	Tel-eosts	Mitigation hierarchy tier[1]	Com-mercial use?	Observer or EM coverage required for compliance monitoring?
Forage fish bait vs. squid bait	Y	▼ ? ?	▲ ▲ ?	▲ ▲ ?	— ? —	— ▲ —	▲ ▲ ▼	▲ ▲ ▼	▲ V ?	Minimize-PCMR Minimize-BR Minimize-PCMR	Y	N
Deeper (hooks fish >100 m) daytime fishing	N	? ?	▲ ▼	▲ ▼	▲ ?	▼ ▼	▲ ▼	▼ ▼	V V	Minimize-BR NA	Y	N
Minimum depth of shallowest hook (min. distance of 1st branchline from floatline, min. length of branchlines and floatlines)[7]	N	— —	▲ —	▲ —	▲ —	— —	▲ —	— —	V —	Minimize-BR NA	Y	Y
Ban lightsticks	N (lightsticks are not used but are not banned)	— —	▲ —	▲ —	— —	— —	? —	▲ —	V —	Minimize-BR NA	Y	N
Light emitting devices that have wavelenghts and a flicker rate that reduce detection by marine turtles	N	— —	▲ —	▲ —	? —	— —	? —	? —	? —	Minimize-BR NA	Y	N
Branchline longer than floatline	N	— —	— ▲	— ▲	— —	— ?	— —	— —	— —	NA Minimize-PCMR	Y	N
Single baited instead of threaded bait on hook (Note -	N	?	▲	?	?	▲	?	?	▲	Minimize-BR	Y	Y

Method	Used by Tunago fishery?	Cet-aceans	Turtles-hard-shelled	Turtles-leather-back	Rays	Sea-birds	Sharks-epi-pelagic	Sharks-meso-pelagic	Tel-eosts	Mitigation hierarchy tier[1]	Com-mercial use?	Observer or EM coverage required for compliance monitoring?
for seabird catch risk, bait hooked in the head or tail may have a faster sink rate than when hooked in the center of their body, and possibly faster than multiple threaded hook)		—	—	—	—	—	—	—	—	NA		
Seabirds[8]												
Branchline weighting (conventional, crimped in place)	Y	— —	— —	— —	? —	▲ —	? —	? —	? —	Minimize-BR NA	Y	N
Branchline weighting (sliding weight)	N	— —	— —	— —	? —	▲ —	? —	? —	? —	Minimize-BR NA	Y	Y
Night setting (and shallow-set fishing)	N	? —	▼ ▲	▼ ▲	▼ —	V ▲	▼ ▲	▲ ▲	V V	Minimize-BR Minimize-PCMR	Y	N
Tori line (single, paired)	Y (single) but design is not known	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Hook shielding devices	N	— —	? —	? —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Side setting	N	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y

Method	Used by Tunago fishery?	Cet-aceans	Turtles-hard-shelled	Turtles-leather-back	Rays	Sea-birds	Sharks-epi-pelagic	Sharks-meso-pelagic	Tel-eosts	Mitigation hierarchy tier[1]	Com-mercial use?	Observer or EM coverage required for compliance monitoring?
Underwater setting devices	N	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Blue-dyed and thawed bait	N	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Ban live bait	N (frozen bait is used, but live bait is not banned)	? —	? —	? —	? —	▲ —	? —	? —	? —	Minimize-BR NA	Y	N
Bird curtain	N	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Prohibit discharge of spent bait and offal during setting and hauling	N	? —	? —	? —	? —	▲ —	? —	? —	? —	Minimize-BR NA	Y	N
Minimize deck lighting during night setting	N	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Towed buoy	N	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Branchline length < distance between coiler and stern	Unknown	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y

Method	Used by Tunago fishery?	Cet-aceans	Turtles-hard-shelled	Turtles-leather-back	Rays	Sea-birds	Sharks-epi-pelagic	Sharks-meso-pelagic	Tel-eosts	Mitigation hierarchy tier[1]	Com-mercial use?	Observer or EM coverage required for compliance monitoring?
Bait casting machine / no setting hooks into propeller turbulence	Unknown	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Bait-swim bladder punctured/species without swim bladders	N (current species used for bait lack swim bladders, but not required)	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Bait thaw status (use fully thawed fish bait and partially thawed squid bait; ban the use of frozen bait)	Unknown	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Bait hooked in the head or tail, and not in the center	Unknown	— —	— —	— —	— —	▲ —	— —	— —	— —	Minimize-BR NA	Y	Y
Sharks												
Monofilament leaders only (ban wire and multifilament leaders)	Y	▼ ?	? —	? —	— —	? —	▲ —	▲ —	? —	Minimize-BR Minimize-PCMR	Y	N
Ban shark lines (branchlines that fish near the surface, through attachment to floats or floatlines)	Y	— —	▲ —	▲ —	▲ —	— —	▲ —	— —	V —	Minimize-BR NA	Y	Y
Ban shark lazy line	N	—	—	—	—	—	—	—	—	NA	Y	Y

Method	Used by Tunago fishery?	Cet-aceans	Turtles-hard-shelled	Turtles-leather-back	Rays	Sea-birds	Sharks-epi-pelagic	Sharks-meso-pelagic	Tel-eosts	Mitigation hierarchy tier[1]	Com-mercial use?	Observer or EM coverage required for compliance monitoring?
		—	—	—	—	—	▲	▲	—	Minimize-PCMR		
Relatively long branchlines (to increase rate of at-vessel survival of obligate ram-ventilating sharks)	Y	—	—	—	—	—	—	—	—	NA	Y	N
		—	▲	▲	—	—	—	▲	V	Minimize-PCMR		
Ban shark finning	Y	—	—	—	—	—	—	—	—	NA	Y	N
		—	—	—	—	—	V	V	—	Minimize-PCMR		
Retention ban - oceanic whitetip and silky sharks	Y	—	—	—	—	—	—	—	—	NA	Y	N
		▲	▲	▲	▲	▲	▲	▲	▲	Minimize-PCMR		
Repellants (e.g., rare earth electropostive metals, chemical/olfactory, electrical, magnetic)	N	?	?	?	?	—	?	?	?	Minimize-BR	Y	Y
		—	—	—	—	—	—	—	—	NA		
Rays												
See 'wider hook'	Y											
See 'deeper daytime fishing'	N											
See 'minimum depth of shallowest hook'	N											
See 'ban shark line'	Y											
See 'retention ban'	N (but not retained due to lack of market value)											

[1] Mitigation hierarchy tiers:
Avoid-BR = Eliminate the bycatch risk of one or more species or assemblage completely within the scope of the intervention

Minimize-BR = Reduce the bycatch rate of one or more species or assemblage
Avoid-PCMR = Eliminate post-capture mortality risk
Minimize-PCMR = Reduce PCMR of a species or assemblage
Offset = obtain an equivalent gain to replace any residual bycatch fishing mortality, or obtain a net gain

[2] See Supplemental Material of Gilman et al. (2021a) for a review of bycatch quotas and weak hooks.

[3] For instance, electronic tracking of gear position, no hooks in discarded spent bait, marking gear to increase visibility, using less-durable and biodegradable materials for fishing gear components, and disabling or removing derelict gear, develop and implement MARPOL garbage management plans.

[4] A very limited body of research suggests that reducing the duration of daytime gear haulback and possibly total soak duration may reduce loggerhead catchability, reducing the duration that gear soaks at night might reduce leatherback catchability, and reducing total soak time might reduce at-vessel mortality rates of all turtle species (FAO, 2010; Ferreira et al., 2011; Epperly et al., 2012).

[5] Reduces catch risk of unwanted bluefin tuna (Foster and Bergmann, 2012), but may also reduce catch risk of targeted and incidental marketable species (e.g., bigeye tuna, spearfish) (Bigelow et al., 2012), and due to required use of more durable leaders, may increase the catch risk of some shark and unwanted teleost species by reducing their ability to sever the line.

[6] Two studies found no significant difference in albatross catch rates between wider circle and narrower J-shaped hooks (Domingo et al. 2012; Gilman et al. 2016c). Two studies observed that wider circle hooks had lower catch rates of primarily gulls (Laridae) and shearwaters (Procellariidae) than narrower J-shaped hooks, (Hata, 2006; Li et al., 2012). This suggests that catch risk response to hook type may only be important for relatively small seabird species.

[7] Note: regulations for the American Samoa albacore longline fishery require ≥30 m float lines, ≥10 m branchlines, and ≥70 m between floatlines and first branchlines in order to have all hooks fish >100 m. Longer floatlines are not recommended, as this reduces the probability that captured marine turtles and other air-breathing species will survive the gear soak.

[8] Note: A mainline line shooter was not included as a bycatch mitigation method. This equipment has been incorrectly considered as a method to mitigate seabird bycatch rates. However, the sink rate of baited hooks will be unaffected by the sink rate of the mainline until the hook has settled to the full length of the branchline, which in most fisheries is below the depth where seabirds can dive (for details, see WPRFMC, 2018).

APPENDIX 2. Example Approach for Ranking Commercial Viability Attributes

Table 5 was used in an expert survey to rank seabird bycatch mitigation methods for relative practicality, safety and economic viability (Gilman et al., 2021a). Experts completed a survey to provide their perspectives on the relative commercial viability of alternative seabird bycatch mitigation methods for use by pelagic longline fisheries during setting and gear retrieval. The survey form directions explained that, while rankings are requested by individual method, combinations of methods may be optimal, which would be taken into account by the participants when discussing and interpreting the survey findings. Definitions of the three commercial viability criteria and directions for scoring were:

- **Practicality**: Relative effect of the method on convenience for fishers (e.g., increases crew exposure to waves; requires time in between fishing operations, reducing available free time)
  Score from 1 (extremely impractical) to 10 (no change in conventional fishing practices, or makes operations more convenient)
- **Crew safety**: Does use of the method create a safety risk for crew?
  Score from 1 (large safety risk to crew) to 10 (no safety risks)
- **Economic viability**: Does use of the method reduce revenue, such as by reducing the catch rates or quality of marketable species, reducing fishing effort, or constraining access to fishing grounds or seasons with high catch rates of marketable species; or increase costs, such as by increasing fuel consumption, or increasing costs for the initial outlay or replacement of gear or vessel equipment.
  Score from 1 (high economic costs) to 10 (no additional economic costs or improves economic viability)

Table 5. Expert survey to rank the commercial viability of alternative seabird bycatch mitigation methods for pelagic longline fisheries.

Method	**Practical** (1-10)	**Safe** (1-10)	**Economic cost** (1-10)
Area-based management - move-on rule in combination with fleet communication			
Area-based management - reduce fishing effort at areas documented to have highest seabird catch rates			
Area-based management - reduce fishing effort during months with highest seabird catch rates			
Automatic branchline coiler			
Bait - artificial			
Bait - forage fish species only			
Bait - fully thawed fish			
Bait - no live bait			
Bait - thread hook in the head or tail, not in the center of the bait			
Bait - use species lacking swim bladder or puncture bladders			
Bait casting machine			

Method	**Practical** (1-10)	**Safe** (1-10)	**Economic cost** (1-10)
Bird curtain			
Blue-dyed bait			
Branchline length < distance between coiler and stern			
Branchline weighting design –increase from 45g and/or reduce leader length from 0.6m			
Fleetwide bycatch quota, triggers additional bycatch mitigation method requirements			
Handling and release methods			
Hook shielding devices			
Individual transferrable bycatch quota, triggers additional bycatch mitigation method requirements			
Individual vessel reward for annual seabird bycatch rate below threshold			
Minimize deck lighting during night setting			
Night setting			
No setting hooks into propeller turbulence			
Offset through levy defined by species, and whether is released alive or discarded dead, to fund threat mitigation at seabird colonies			
Retain offal, spent bait and dead discards during setting and hauling			
Side setting			
Specifications for mainline maintenance to reduce the probability of tangles that bring baited hooks to the surface			
Tori line			
Towed buoy			
Underwater setting devices			

APPENDIX 3. Ranks of Shortlisted Bycatch Mitigation Methods

Table 6 presents the mean scores assigned to each of the shortlisted bycatch mitigation methods. For the first three criteria, a score is assigned based on the effect of the measure for the taxonomic group in which the measure is included. For example, use of circle vs. J-shaped hooks is assessed for effects on marine turtles' catch rate (benefits leatherback turtles, no effect on hardshelled turtles) and fishing mortality (benefits all turtles), and conflicting effects on other vulnerable species (increases shark catch rates, variable effect on catch rates of teleosts). And, for example, area-based management tools are assessed across taxonomic groups – they can reduce bycatch rates by protecting bycatch hotspots for some species, but displaced effort can exacerbate the catch rates of other vulnerable species, causing multispecies conflicts (Gilman et al., 2019).

A score of 1 indicates that the measure has a strong adverse effect on that criterion, a 5 indicates minimal or no effect, while a score 10 indicates a strong positive effect. For example, employing prescribed handling and release methods has no effect on catch risk and no multispecies conflicts, and hence is assigned a score of 5 for these criteria. It may increase post-release survival and thus is assigned a score of 8 for the fishing mortality criterion. This measure is assigned a low score of 2 for enforceability by the Vanuatu government because compliance monitoring requires at-sea monitoring by observers or EM, and currently there is very limited capacity for at-sea monitoring.

For measures that are already in use, the measure is scored based on whether the measure continues to be implemented relative to being replaced by an alternative to the measure. For example, because the fishery is currently using medium-sized circle hooks, the measure 'circle hooks required instead of J-shaped hooks' is scored based on the estimated effect of continued use of medium-sized circle hooks instead of J-shaped hooks of a similar size.

Table 6. Results of expert survey to rank the efficacy at meeting objectives on mitigating the catch and mortality risks of threatened bycatch species, costs from multispecies conflicts, costs to commercial viability, and suitability for compliance monitoring of alternative, shortlisted bycatch mitigation methods for the Tunago-owned, Vanuatu-flagged pelagic longline fishery. Scores are on a scale of 1 to 10, with 1 being strongly adverse and 10 being strongly positive.

Method	Reduce bycatch rate	Reduce fishing mortality	Costs – multi-species conflicts	Costs - practicality, safety or economic viability	Enforce-ability by Vanuatu government	Comments
Inter-taxa						
Handling and release best practices	5	8	5	4	2	An existing practice through relevant IATTC and WCPFC measures, but requires confirmation that required equipment is onboard and being employed to prescription.

Method	Reduce bycatch rate	Reduce fishing mortality	Costs – multi-species conflicts	Costs - practicality, safety or economic viability	Enforce-ability by Vanuatu government	Comments
Move-on rule	7	5	7	4	2	Could be combined with a fleet communication measure.
Mitigate risk of producing derelict gear and adverse effects	6	6	5	4	4	Measures such as banning toxic materials for gear components (e.g., lead swivels) and requirements related to using radio buoys to track the position of the unattended gear can undergo surveillance partially via dockside inspections, and through observer and EM coverage. Observer and EM coverage can detect some instances of discarding damaged gear. ALDFG from industrial pelagic longline fisheries is considered a relatively low risk (Gilman et al., 2021c).
Retention ban	6	8	5	3	6	To determine the feasibility for compliance monitoring, need more information on monitoring systems for at-sea transshipment and port sampling.
Retention limit (individual or fleet-based, market species of sharks, teleosts)	6	8	5	3	6	To determine the feasibility for compliance monitoring, need more information on monitoring systems for at-sea transshipment and port sampling.
Soak duration limit	6	7	7	3	2	May reduce the catch rate and increase the haulback survival rate (the longer the time an organism spends captured before haulback, the higher the haulback mortality rate) for some species. Given the current long gear soak, a reduction could represent a substantial change in practice, where the effect on economic viability from changes in catch rates and quality of marketable species is not known.
Offsets: residual bycatch mortalities that were not avoided and minimized are offset by obtaining an equivalent gain (no net	6	6	5	3	2	Offset programs can be designed to create an incentive to avoid and minimize catch and mortality. Can employ a combination of levies (bycatch tax) to offset vulnerable bycatch and

Method	Reduce bycatch rate	Reduce fishing mortality	Costs – multi-species conflicts	Costs - practicality, safety or economic viability	Enforce-ability by Vanuatu government	Comments
loss/bycatch-neutral), or a more-than-equivalent net gain – implemented through a combination of levies (penalties) and rewards						rewards when threshold bycatch rates or levels are met.
Area-based management tools (static and dynamic)	8	5	3	2	9	Note, static closures around shallow submerged features was eliminated by the catch sector as a candidate measure. Other candidate static ABMTs include restrictions on fishing during relevant seasons in areas near albatross and petrel breeding colonies, marine turtle nesting sites, areas of predictable shark aggregations, migratory corridors, etc. Dynamic ABMTs would be substantially more challenging for Vanuatu government compliance monitoring relative to static measures.
Fleet communication	7	5	7	5	2	More information is needed on whether and how the vessels of the fishery coordinate the location of fishing effort, and whether the vessels communicate and coordinate fishing positions with any other fleets. Could be combined with a move-on-rule measure.
Cetaceans						
Mainline length limit	6	7	7	3	2	See soak duration
Acoustic masking - quieter vessels	6	5	5	3	9	Limited evidence of long-term efficacy at reducing odontocete catch risk, and thus may not be worth the potentially high cost to retrofit vessels.
Marine turtles						
Circle hooks required instead of J-shaped hooks of the same width, with no more than 10 degree offset	7	9	3	5	4	Vessels currently use medium-sized (ca. 16/0) circle hooks.

Method	Reduce bycatch rate	Reduce fishing mortality	Costs – multi-species conflicts	Costs - practicality, safety or economic viability	Enforce-ability by Vanuatu government	Comments
Wider hook	7	5	4	3	4	Hook width effects on species-specific shark and teleost catch rates are variable by fishery, season and depending on the difference in hook widths being compared (Gilman et al., 2018). There is a risk that fishing with a wider hook could increase catchability of other vulnerable shark and teleost species and risk of decreased catch rates of marketable species.
Wider circle v. narrower J-shaped hook	9	9	3	5	4	Vessels currently use medium-sized (ca. 16/0) circle hooks.
Forage fish bait vs. squid bait	8	4	10	6	4	Vessels currently use forage fish species for bait.
Minimum depth of shallowest hook (min. distance of 1st branchline from floatline, min. length of branchlines and floatlines)	9	4	4	4	2	Having shallowest branchlines (those closest to floatlines) fish deeper, ideally below 100 m, would reduce catch rates of epipelagic species, may reduce haulback survival rates of marine turtles and possibly seabirds, and may increase catch rates of mesopelagic species.
Ban lightsticks	8	5	7	3	4	The vessels do not use lightsticks. May reduce catch rates of some marketable species, but also result in reduced catchability of other vulnerable species (e.g., marlins, possibly seabirds during night setting, possibly some species of sharks but maybe no effect on rays).
Branchline longer than floatline	5	7	6	5	4	Needed just for the shallowest branchlines, closest to floatlines. May also enable higher seabird haulback survival rates on these branchlines nearest to floatlines.

Method	Reduce bycatch rate	Reduce fishing mortality	Costs – multi-species conflicts	Costs - practicality, safety or economic viability	Enforce-ability by Vanuatu government	Comments
Single baited instead of threaded bait on hook	6	5	6	4	2	Need to confirm whether this is a current practice. May reduce hardshelled turtle and possibly seabird and teleost catch rates. Also, see seabirds section, where, for seabird catch risk, bait hooked in the head or tail may have a faster sink rate than when hooked in the center of their body, and possibly faster than multiple threaded hook.
Seabirds						
Branchline weighting (conventional lead-centered swivel, crimped in place)	6	5	5	4	4	Current branchline weighting design does not meet ACAP guidelines or IATTC or WCPFC measures.
Branchline weighting (sliding weight)	6	5	5	4	3	Current branchline weighting design does not meet ACAP, IATTC or WCPFC measures. Sliding weights would reduce but not eliminate safety risks to crew from placing weights closer to hooks. Because sliding weights can be easily moved during a fishing trip, dockside monitoring is an ineffective compliance monitoring approach.
Tori line (single, paired)	7	5	5	4	2	Vessels currently use single tori lines. Confirmation that designs meet IATTC and WCPFC requirements is needed.
Ban live bait	7	5	5	4	2	Live bait is not used by the vessels.
Bird curtain	6	5	5	4	2	Tori line use during the set precludes the addition of a bird curtain, but a bird curtain could reduce bird catch risk during the haul. Need to assess available monitoring data to determine the magnitude of bird captures during hauling to determine the capacity for reduced seabird catch.

Method	Reduce bycatch rate	Reduce fishing mortality	Costs – multi-species conflicts	Costs - practicality, safety or economic viability	Enforce-ability by Vanuatu government	Comments
Prohibit discharge of spent bait and offal during setting and hauling	6	5	5	3	2	While there is limited evidence, current understanding is that the discharging of offal and spent bait during fishing increases the density of seabirds attending vessels, increasing seabird catch rates in the long term.
Minimize deck lighting during night setting	6	5	5	4	2	Positioning deck lights to avoid and minimize coverage of areas where baited hooks enter the water can reduce seabird catch risk.
Branchline length < distance between coiler and stern	6	5	5	3	2	See bird curtain
Bait-swim bladder punctured/species without swim bladders	6	5	5	3	2	If a species of bait is used that has swim bladders, a requirement for crew to puncture the swim bladders could present a large cost to commercial viability
Bait hooked in the head or tail, and not in the center	6	5	5	4	2	The mechanistic effect on baited hook sink rate is not well understood across different forage fish bait species, and there is a lack of evidence of an effect on seabird catch rates, and on catch rates of other species, including marketable fishes.
Sharks						
Monofilament leaders only (ban wire and multifilament leaders)	8	6	5	4	4	An existing measure. Reduces shark catch rates, may reduce total shark fishing mortality. Effect on catch rates of marine turtles is not well understood.
Ban shark lines (branchlines that fish near the surface, through attachment to floats or floatlines)	8	5	8	4	2	An existing measure. Would reduce catchability of epipelagic species.
Ban shark lazy line	5	8	5	4	2	For species that have high haulback survival rates, banning lazy lines have the capacity to

Method	Reduce bycatch rate	Reduce fishing mortality	Costs – multi-species conflicts	Costs - practicality, safety or economic viability	Enforce-ability by Vanuatu government	Comments
						substantially increase the proportion that are alive upon release. May reduce practicality.
Minimum branchline length (increase rate of at-vessel survival of obligate ram-ventilating sharks)	4	8	6	5	4	Current lengths used are likely adequate. May benefit marine turtles captured on hooks near floats - see 'branchline longer than floatline' under marine turtles.
Ban shark finning	6	6	5	4	2	Finning ban is an existing measure. Bans on shark finning, where fins are retained and the remaining carcass is discarded, might reduce retention of sharks lacking market value other than for the fins, which in turn might increase post-capture survival. However, for species that are retained for their meat and other products, finning bans may not affect fishing mortality rates, and for species with low haulback mortality rates, finning bans will also not be as effective at reducing fishing mortality.
Retention ban - oceanic whitetip and silky sharks	6	8	5	3	6	See above, under inter-taxa
Rays						
See 'wider hook'	8	5	4	4	4	See above under marine turtles
See 'minimum depth of shallowest hook'	9	5	4	4	2	See above under marine turtles
See 'ban shark line'	8	5	8	4	2	Would reduce catchability of epipelagic species.
See ‘retention ban’	5	5	5	5	6	Rays are not retained due to a lack of market value.