Shark Bycatch Mitigation

DECISION SUPPORT TOOL

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A structured approach to help decision-makers and other stakeholders identify location-appropriate shark bycatch mitigation approaches that can be enabled by EM in all ocean areas with unsustainable shark catch.

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Contents

ACRONYMS

BHRPs Best Handling and Release Practices

DST Decision Support Tool

EM Electronic Monitoring

ETP Endangered, Threatened, and Protected

FIP Fisheries Improvement Project

IUU Illegal, Unreported, and Unregulated

LL Longline

MSC Marine Stewardship Council

NGO Non-governmental Organization

RFMO Regional Fisheries Management Organization

SDM Structured Decision-making

SMART Specific, Measurable, Achievable, Relevant, and Time-bound

TNC The Nature Conservancy

Executive Summary

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Sharks are one of the world's oldest living predators and are now one of the most threatened species, with over one-third of shark species facing extinction as a direct result of overfishing. Despite increasing numbers of international regulations designed to reduce shark fishing mortality over the past decade, shark mortality continues to rise year after year. Fisheries are complex systems that require dynamic and adaptive management solutions and are often heavily influenced by external regulatory and economic drivers, making it challenging to know when, where, and how to drive change in fisheries management, especially when it comes to mitigating shark bycatch.

To combat these challenges, The Nature Conservancy (TNC) conducted an expert-led assessment to identify all possible shark bycatch mitigation measures for pelagic longline, combined trawl (pelagic, midwater, bottom) and combined gillnet (drift and anchored) fisheries (n=37). From here, an expert-informed process determined that, for a majority of the identified shark bycatch mitigation measures (22 of the 37), evidence of implementation at the vessel level can be effectively monitored using electronic monitoring systems. Electronic monitoring (EM)—the use of onboard cameras, GPS, and sensors to capture on-the-water fishing activity—is a critical tool that can be used to collect data to inform fisheries management and science objectives while verifying evidence of regulatory compliance or implementation of voluntary measures, with local, national, and regional regulations, including shark bycatch mitigation measures. Specifically, EM can be a useful tool for verifying that shark bycatch mitigation measures are 1) being implemented properly, and 2) achieving the intended outcome(s), thereby supporting transparent and adaptive fisheries management.

TNC then developed the Shark Bycatch Mitigation Decision Support Tool (DST) **to help decision-makers and other stakeholders identify location-appropriate shark bycatch mitigation approaches that can be enabled by EM in all ocean areas with unsustainable shark catch**. This DST is based on a structured decision-making (SDM) approach intended to guide fisheries stakeholders and decision-makers through a process to clearly identify their shark bycatch problem, management objectives, and the potential management actions that can be taken to meet their objectives. Structured decision-making provides opportunities for stakeholders to engage in the decision-making process, promoting transparency and acceptance of decisions.

This document provides guidance for using the Shark Bycatch Mitigation DST and associated resources to make informed decisions on shark bycatch mitigation actions. It outlines each of the seven steps in SDM and provides resources to support the decision-making process (Figure 1), as outlined below:

STEP 1 | Problem Formulation—*What is the problem we are trying to solve?*

STEP 2 | Setting Clear Objectives—*What do we hope to achieve?*

STEP 3 | Identifying Alternatives—*What could we do?*

STEP 4 | Predicting Consequences—*What are the predicted outcomes of different alternatives and how will they meet objectives?*

STEP 5 | Evaluating Tradeoffs—*What are the tradeoffs among objectives and alternatives?*

STEP 6 | Making Decisions—*What should we do to best achieve our objectives?*

STEP 7 | Act, Monitor and Learn—*Can we design interventions and monitoring to advance learning and adaptive management?*

The Shark Bycatch Mitigation DST also includes explicit examples and hypothetical case studies related to shark bycatch mitigation and is specifically intended to support fisheries and resource managers, governing bodies, NGOs, and other fisheries stakeholders (i.e., skippers, fishers, fishing companies, and FIP managers) in selecting location-appropriate, EM-enabled shark bycatch mitigation measures. Furthermore, EM is an essential tool for supporting adaptive management, which is required to successfully implement and iterate on selected shark bycatch mitigation measures. **This DST is tailored to fisheries that already have an EM program in place or that are committed to implementing an EM program in the near future.** In summary, this document aims to give decision-makers the resources they need to address the urgent threat to shark populations and biodiversity loss by supporting data-driven decision-making for improved fisheries management and ocean health.

Additional resources to support the SDM process include:

- **Appendix A: Fishery Characterization**—*A worksheet designed to help stakeholders characterize the key features of their fishery to frame the shark bycatch problem and decision context.*
- **Appendix B: Mitigation Assessment**—*A list of all EM design considerations to support the decision-making process.*
- **Appendix C: Electronic Monitoring Considerations**—*A list of all EM considerations to work through in the decision-making process.*
- **Appendix D: Shark Bycatch Mitigation DST Worksheet**—*A worksheet with templates designed to support decision-makers in using the DST to identify shark bycatch mitigation strategies for a given fishery.*

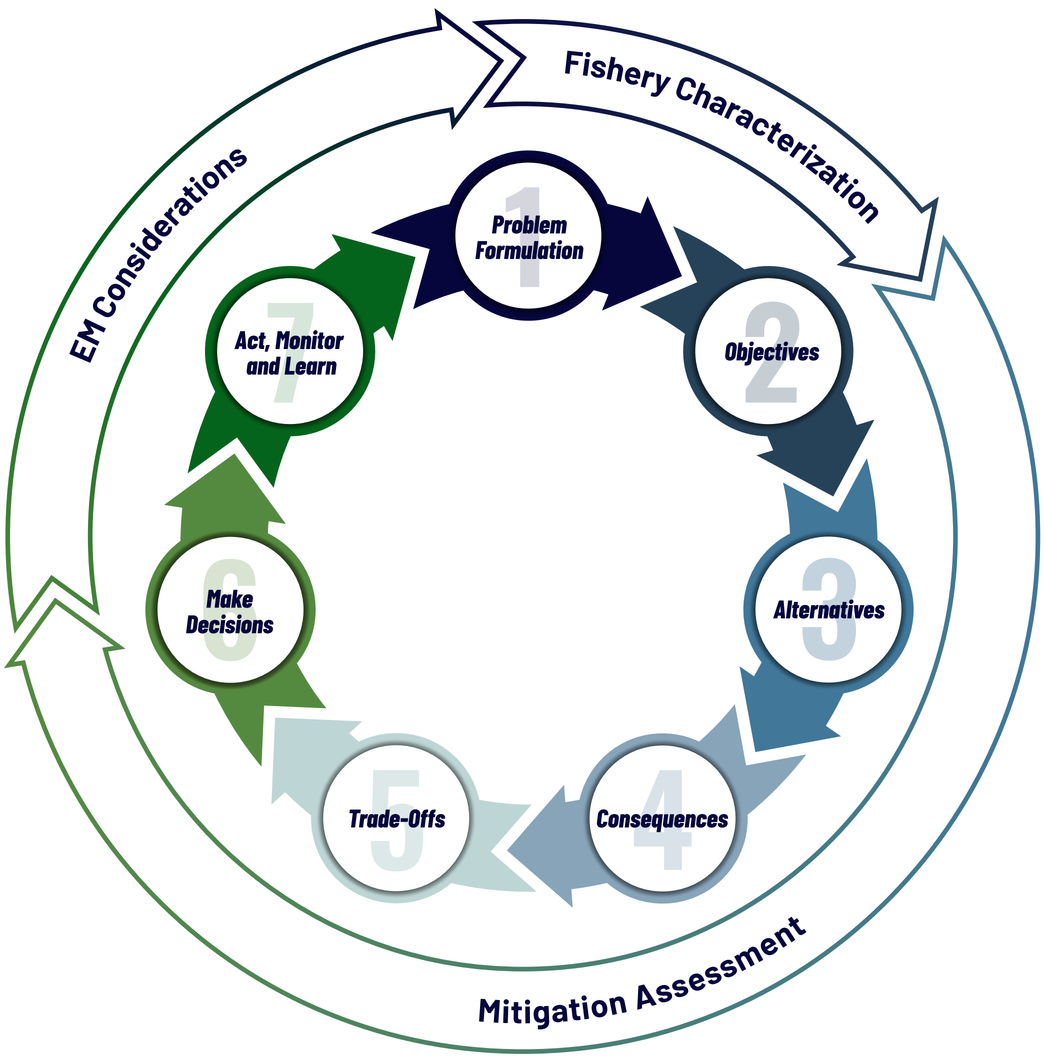

FIGURE 1: Shark Bycatch Mitigation Decision Support Tool (DST). The seven steps in the structured decision making process covered in the Shark Bycatch Mitigation DST. Resources included in this report to support the process are shown next to the relevant steps. All accompanying resources are provided in Appendices A, B, C, D.

1.0 Introduction

1.1 Background

Sharks, one of the most ancient marine predators, have been increasingly recognized among the world's most threatened wildlife due to unsustainable shark fishing (Dulvy et al., 2021; Dulvy et al., 2024). Captured both intentionally and incidentally, shark fishing mortality has increased globally over the past decade, with approximately 80-100 million sharks killed in fisheries each year, despite myriad regulatory interventions intended to address this urgent conservation challenge (Worm et al., 2024). Oceanic sharks and rays, in particular, have declined by more than 70% during the last half-century due to an 18-fold increase in fishing pressure (Pacoureau et al., 2021), diminishing their presence to a shadow of what it once was across their 420-million-year history.

Sharks hold both cultural and economic significance across communities globally (Dulvy et al., 2017). Today, the global value of shark fisheries is estimated at almost USD 1 billion (Dent & Clarke, 2015), and sharks play an important role in nutritional security in many coastal fisheries around the world (Temple et al., 2024). Approximately 9% of the global catch of sharks, representing 33 species across a wide range of life histories, is considered biologically sustainable, suggesting that sustainable shark fishing is feasible (Simpfendorfer & Dulvy, 2017). Yet, even sustainably fished shark species are not necessarily sufficiently managed (Simpfendorfer & Dulvy, 2017).

Many shark species are highly migratory and/or not well studied, making it difficult to understand how, where, and when to implement policies and apply mitigation measures to support both healthy shark populations and the communities that rely on them (Dulvy et al., 2017). This is particularly true for the vast majority of shark catch that is not sustainable (Simpfendorfer & Dulvy, 2017), including the more than 50% of sharks killed by fishing activities globally that are caught incidentally (i.e., as bycatch) and discarded back into the ocean, often without record of ever being caught (Feitosa et al., 2025). Given the range of shark bycatch mitigation strategies available across gear types, the over 500 shark species inhabiting our oceans, estuaries, and freshwater ecosystems, and the complex ecological, social, and regulatory contexts in which these systems and species reside, there is an opportunity to use a structured approach for decision-making to inform and guide sustainable fisheries management decisions to address unsustainable shark bycatch.

However, fisheries (including shark fisheries) often operate in data-limited contexts and with rudimentary management systems, making the identification and design of appropriate shark bycatch mitigation measures challenging (Gilman et al., 2022). The complexity of effective shark management requires a solution that can provide fisheries managers with the tools they need to successfully and sustainably manage their fisheries and mitigate fisheries impacts. To help solve this problem, a recent assessment of gear-specific shark bycatch mitigation measures was conducted by The Nature Conservancy (Gilman, Unpublished Technical Report, 2023). However, this mitigation assessment revealed that nearly all identified shark bycatch mitigation measures appropriate for longline, trawl, and gillnet fisheries (n = 37) require effective at-sea independent monitoring, which is currently lacking on the vast majority of fishing vessels globally (Ewell et al., 2020). This lack of independent, on-the-water monitoring makes it nearly impossible to ensure that fisheries are meeting sustainability requirements. For this reason, many stakeholders have turned to the use of electronic monitoring.

1.2 The Role of Electronic Monitoring

Electronic monitoring (EM)—the use of video cameras, GPS, and sensors to track and verify on-the-water fishing activity—is being used by fisheries managers, regulators, and supply chain actors (including seafood suppliers and retailers). EM records fishing activity and human behavior onboard vessels, providing relevant data to inform stock assessments, detect overfishing, monitor discards and bycatch (including sharks and other endangered, threatened, and protected [ETP] species), observe transshipment events, and examine deck activity for safety violations and non-compliance (including compliance with best handling and release practices [BHRPs]). EM systems have been proven to improve compliance with regulations and fishery performance against sustainability certifications (e.g., Marine Stewardship Council [MSC] certification), increasing the reliability of fisher reporting and enhancing data utility for regulators and decision-makers (SFP, 2024). In verifying on-the-water activities and compliance with sustainability and social responsibility safeguards, EM has the ability to unlock market access for early adopters.

As consumer demand for sustainable products increases, so too does the need to track and verify that seafood products are being harvested in a sustainable manner. EM drives this transparency from the first step, initial harvest, which is critical for enabling effective tracking and verification of seafood throughout the entire supply chain. Several supply chain actors are heavily invested in advancing transparency by maintaining rigorous sustainability certifications and/or joining economic initiatives like the Tuna Transparency Pledge—a global initiative aiming to unite actors throughout the supply chain to achieve 100% on-the-water monitoring on all industrial tuna vessels by 2027. Today, global fisheries are forced to meet sustainability demands to secure their market access and EM is a critical tool for doing so in a feasible and cost-effective manner.

Many fisheries with shark bycatch are data-limited, with insufficient information to inform appropriate management measures (Oliver et al., 2015; Cortes and Brooks, 2018). EM can play a pivotal role in addressing shark bycatch by providing high-resolution, at-sea monitoring data thereby providing a key enabling condition for the majority of shark bycatch mitigation measures. Furthermore, EM can support fisheries management science by collecting data required to support shark population stock status assessments and to determine if selected bycatch mitigation measures are having the desired effect on shark populations (Cortes and Brooks, 2018). Although several fisheries use human observers to serve similar roles, the cost of human observer programs can be quite high, limiting the scalability of this kind of monitoring. EM also overcomes sources of statistical sampling bias found in some observer programs (e.g., observer effect, observer displacement effect, etc.). Overall, the cost-effective, comprehensive monitoring, and high-resolution data from EM increases the suite of viable shark bycatch mitigation measures that can be implemented and effectively monitored within a given fishery.

Box 1. Supporting EM-enabled mitigation strategies

The Shark Bycatch Mitigation DST is focused on EM-enabled strategies and is therefore designed for fisheries with shark bycatch concerns that already have EM programs in place or are planning to implement an EM program. The DST is designed to support stakeholders and decision-makers in identifying location-appropriate shark bycatch mitigation measures to address their specific shark bycatch concerns, promote sustainable management, and protect threatened species.

1.3 Addressing Shark Bycatch with a Decision Support Tool

The purpose of this document is to **provide guidance on how to use the Shark Bycatch Mitigation Decision Support Tool (DST) to help decision-makers and other stakeholders identify location-appropriate shark bycatch mitigation measures that can be enabled by EM in all ocean areas with unsustainable shark catch**. Importantly, this DST assumes that there is a concern about unsustainable shark fishing and/or threatened species within the fishery. Further, the DST is geared towards supporting fisheries that already have EM programs in place or are looking to develop and implement EM programs (Box 1). The intended audiences of this document are fisheries managers, local, regional and national governing bodies, fishery improvement project (FIP) implementers, skippers, fishers, NGOs, EM specialists and other stakeholders engaged in shark bycatch management and conservation efforts around the world.

Structured decision-making (SDM) is a core part of this tool and can help to organize a decision process, support stakeholder engagement, ensure that objectives are clear and value-based, and provide transparency on criteria and trade-offs considered during decision-making (Conroy and Peterson, 2013). This document applies SDM principles to the conservation challenge of mitigating shark bycatch via the Shark Bycatch Mitigation DST, providing guidance, explicit examples and hypothetical case studies to support a decision-making process. *Importantly, this document is not the result of an SDM process, and users will need to bring new information and critical thinking to their own use cases.*

This DST aims to drive science-based decisions on the selection of EM-enabled shark bycatch mitigation measures, as well as decisions on other enabling conditions and monitoring needs to support successful implementation. By identifying the most suitable EM-enabled shark bycatch mitigation approaches based on fishery-specific characteristics, this DST will support stakeholders in determining which measures will best address the urgent threat to shark populations given the context-specific realities of existing regulations and economic and livelihood considerations. The anticipated stakeholder outcomes will enable informed decision making to achieve improved fisheries management that supports ocean ecological health.

NOTE: Many RFMOs have existing conservation and management measures requiring the use of various bycatch mitigation measures and best handling and release practices for sharks. In working through this DST, decision-makers should always consider the requirements of relevant RFMOs where they're seeking to apply new management measures. Any outcomes of the DST should be supplemental to RFMO requirements. A list of RFMO resources is provided in Appendix E.

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2.0 Overview of the Shark Bycatch Mitigation Decision Support Tool

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The Shark Bycatch Mitigation DST can help inform decisions about relevant shark bycatch mitigation measures across different types of shark catch and in varying fishery contexts. Fishery management decisions can be difficult when they involve differing values, multiple objectives, limited resources, and uncertainty (Hemming et al., 2021). Decisions on shark bycatch mitigation measures need to be location-appropriate, gear-specific, and appropriate for the type of shark catch that characterizes the fishery (see Box 2). The selected bycatch mitigation measures should be high-impact and feasible given the fishery context, policy constraints, and market conditions. It is also important to understand which shark bycatch mitigation measures can (and cannot) be effectively enforced and assessed using EM to monitor for compliance and track resulting changes to shark catch and fishing-associated mortality.

This DST builds on decision support efforts previously developed to help identify bycatch mitigation approaches based on how they address catch and mortality rates and the strength of evidence for their effectiveness (Gilman et al., 2022). The Shark Bycatch Mitigation DST focuses on supporting mitigation decisions in data-limited contexts and emphasizes the important role of EM-enabled mitigation measures in supporting sustainable shark catch and protecting threatened shark species. Electronic monitoring plays a key role in providing scientific data to support the evaluation of the effectiveness of mitigation measures, as well as promoting and measuring compliance with those measures.

The Shark Bycatch Mitigation DST uses structured decision-making as a core decision analysis approach (Conroy and Peterson, 2013), with guidance and resources tailored to making shark bycatch mitigation decisions that are fishery appropriate. The Shark Bycatch Mitigation DST consists of the following components (Figure 1):

- **Structured Decision-Making**—a 7-step process to reach informed, transparent decisions about shark bycatch mitigation measures.
- **Fishery Characterization**—guidance on characterizing the fishery using available data and information to identify and frame the shark bycatch problems that need to be addressed. This component informs the SDM process and should be completed first.

- **Mitigation Assessment**—a qualitative assessment of 37 shark bycatch mitigation measures evaluated across 11 criteria, including the identification of a subset of mitigation measures that can be enabled by EM. This component informs the identification of mitigation alternatives and the decision analysis portion (Steps 3-6) of the SDM process.
- **Electronic Monitoring Considerations**—a qualitative assessment to identify key considerations for effectively using EM for monitoring and compliance. This component informs the final step (Step 7) of the SDM process.

Box 2. Shark catch typology

This typology characterizes the nature of the shark catch and the fate and life status of the sharks once they are caught and can be an important factor in identifying appropriate mitigation measures. Many fisheries have more than one shark catch typology depending on species caught, season, economic drivers and other factors.

» **TYPE 1 | Sharks targeted.** Sharks are the main target species, where sharks are the largest proportion of the retained catch. Retained sharks include the carcass and not just fins.

» **TYPE 2 | Sharks retained, incidental catch.** Some or all species of sharks are typically retained, though sharks are not the largest proportion of the retained catch. Retained sharks include the carcass and not just fins.

» **TYPE 3 | Shark fins retained, remaining carcass discarded.** Sharks are not the main target of the fishery. For some or all species of captured sharks, the fins are typically retained and the remaining carcass is discarded.

» **TYPE 4 | Sharks not retained.** Sharks are not typically retained, including the fins.

2.1 Why a Structured Decision-Making Approach?

Structured decision-making is an organized analysis of a problem in order to reach a decision. It helps structure the thinking process so that decisions are informed and transparent, and the alternatives selected are defensible and likely to achieve desired outcomes (Hemming et al., 2021). Structured decision-making has been widely used in natural resource management contexts and was developed by the U.S. Fish and Wildlife Service and U.S. Geological Survey (Conroy & Peterson, 2013; Runge et al., 2017). In the marine realm, SDM has been used to guide critical decisions in fisheries management (Koehn et al., 2020; Estévez et al., 2020; Gammage & Jarre, 2020; McGowan et al., 2015), imperiled species management (Welch et al., 2019), and ecosystem-based management (Espinosa-Romero et al., 2011).

There are many challenges, issues, and opportunities for improvement within fisheries that have shark bycatch which could benefit from an SDM approach to identify mitigation measures to improve the sustainability of shark populations. As a core part of the Shark Bycatch Mitigation DST, SDM can help guide managers, practitioners, the fishing industry, and others involved in making decisions about bycatch mitigation in a manner that improves the chances of achieving desired outcomes and informs learning and adaptive management over time (Box 3). Through a structured process, decision-makers and stakeholders clearly identify the type of shark bycatch problem or challenge that needs to be addressed, the management objectives, and the potential management actions that can be taken to meet the objectives. By using models, tools, or expert judgment to predict or anticipate the likelihood of potential actions to achieve objectives, decision-makers can evaluate consequences, trade-offs, risks, uncertainties, and feasibility of different alternatives in a transparent manner (Figure 2).

Box 3. What are the benefits of an SDM approach?

» Organizes the analysis of a problem to reach an informed decision focused on achieving management objectives.

» Supports stakeholder engagement, with stakeholder values expressed as objectives.

» Encourages a transparent process for making informed decisions in the face of uncertainty.

» Promotes learning, the incorporation of new knowledge, and adaptive management.

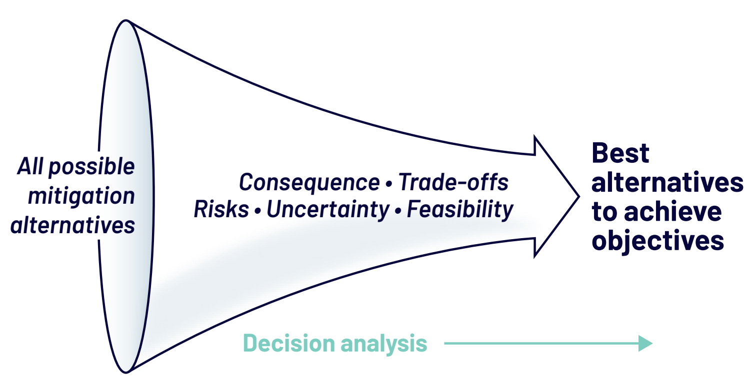


FIGURE 2: Making informed decisions

2.2 The 7 Steps in Structured Decision-Making

The SDM process was adapted here with the addition of a seventh step focused on monitoring to support learning and adaptive management. In the data-limited context of most global shark catch, this monitoring component is key and EM has an important role to play.

Each of the seven steps in SDM aims to address a guiding question (Figure 3; Runge et al., 2013). In Steps 1 and 2, decision-makers and stakeholders clearly identify and define the shark bycatch mitigation problem or challenge being addressed, who needs to be involved, and the management objectives to establish the decision context. Steps 3 through 5 focus on decision analysis of potential mitigation alternatives to decide on the best actions to meet the objectives. By using simple models, decision analyses, or expert judgment to predict how potential management actions may meet identified objectives, decision-makers can evaluate trade-offs, risks, uncertainties, and feasibility in a science-based and transparent manner to reach a decision on the best actions (Step 6). Step 7 focuses on implementing the decision and monitoring to inform learning and adaptive management.

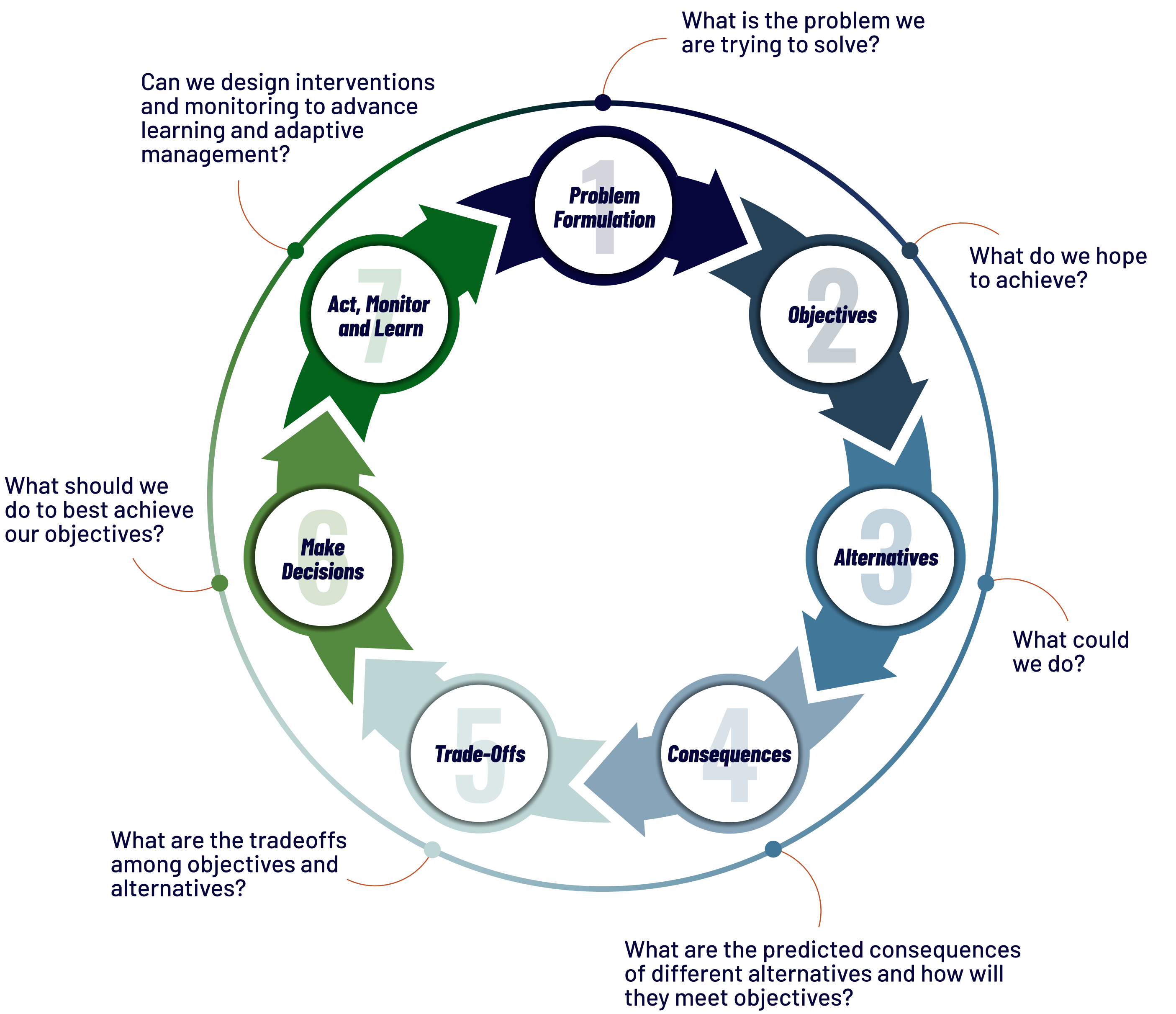


FIGURE 3: The seven steps of Structured Decision-making

Shark bycatch mitigation and monitoring decisions could be improved by implementing this SDM process and explicitly evaluating the relationship between the desired objectives and the alternatives being considered. While data on shark bycatch is limited in many fisheries, identification and implementation of fishery appropriate mitigation measures, verified through the use of EM, can help to address concerns about shark populations (Feitosa et al., 2025; Tolotti et al., 2015). More complex decisions, with a high degree of uncertainty or potential risks, may warrant a more robust analysis and a larger investment of time and resources. Using EM to help fill key data gaps can address uncertainty and inform future decisions.

Guidance on how to navigate each of the seven steps in the SDM process to identify shark bycatch mitigation measures that are enabled by EM is provided in the respective sections below, along with guidance on how to use the resources provided to support the process (Appendix A, B, C). Two hypothetical case studies are also provided (Section 10) to illustrate the decision-making process in a shark bycatch context. A worksheet with prompts and templates is provided in Appendix D to support a shark bycatch mitigation SDM process.

2.3 Fishery Characterization Questionnaire

It is important to compile the best available data and information to characterize the fishery to better understand the shark bycatch issue(s) and decision context (Figure 4). Characterizing the fishery and compiling available information provides a foundation for Step 1 ("Problem Formulation") of the SDM process and should be completed before a decision-making process focused on bycatch mitigation is initiated.

A Fishery Characterization Questionnaire is provided in Appendix A to guide the compilation of best available information. This document provides guiding questions in four topic areas (fishery characteristics, shark catch characteristics, human/management context, and existing monitoring programs and data) with the goal of bringing together relevant information to define the shark bycatch problems or challenges that need to be addressed and the context in which decisions will be made.

To complete the questionnaire, it may be necessary to conduct interviews with experts including fishery participants, as well as compile and analyze available data that could support decisions on mitigation. Most fisheries will not have enough information to answer all the questions; some questions may not be relevant to all fisheries and do not need to be answered. The completed Fishery Characterization allows participants in the decision-making process to have a shared understanding of the fishery, the shark bycatch and data-limitations problems that need to be addressed, and the types of decisions that are needed to achieve the desired outcomes.

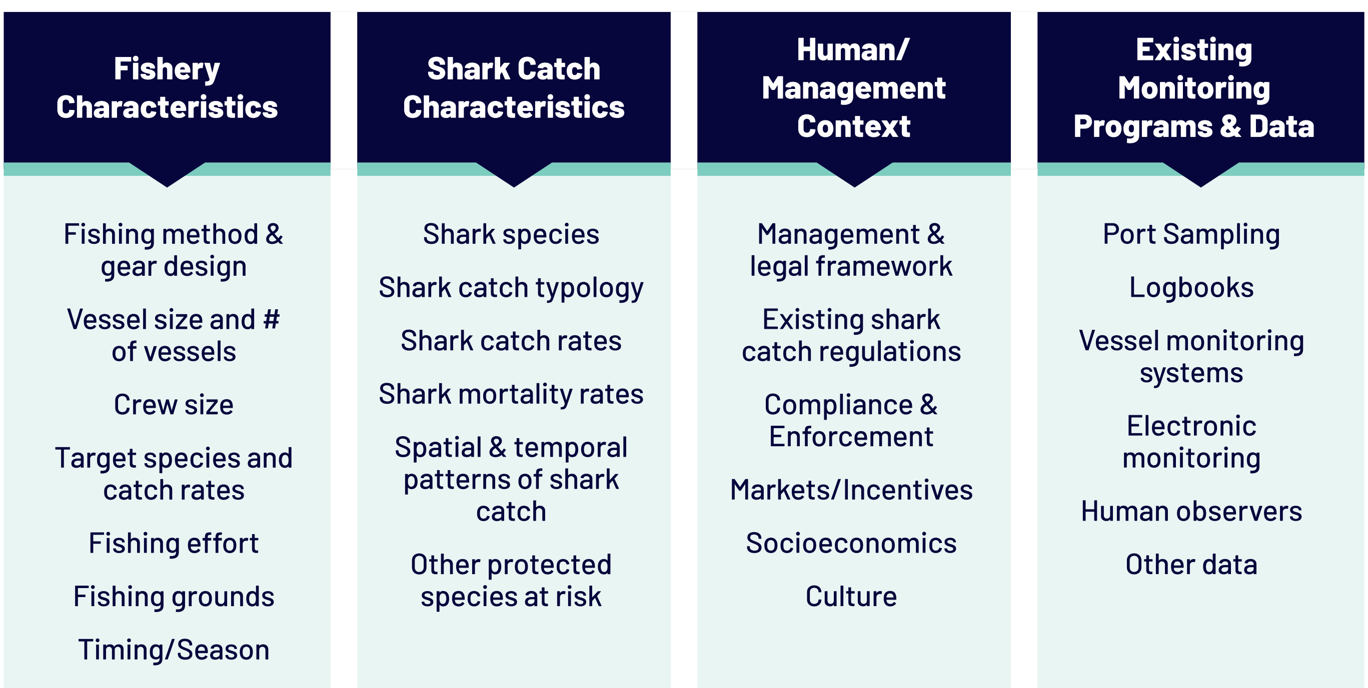


FIGURE 4: Fishery Characterization—to inform a shared understanding of the shark bycatch issues and decision context.

2.4 Assessment of Shark Bycatch Mitigation Measures

Another key resource to support the decision-making process is the Assessment of Shark Bycatch Mitigation Measures, hereafter referred to as the "Mitigation Assessment" (**Appendix B**). The Mitigation Assessment provides an expert-informed, qualitative assessment of 37 different mitigation measures that have been documented to mitigate shark bycatch in pelagic longline, combined trawl (pelagic, midwater, bottom) and combined gillnet (drift and anchored) fisheries across 11 different criteria (Gilman, Unpublished Technical Report, 2023; **Appendix B**).

Each mitigation measure was assigned to a sequential mitigation hierarchy tier—avoid, minimize, remediate, and offset—based on Gilman et al. (2022) to prioritize actions that would be most effective at avoiding harm and minimizing impact over those that only aim to repair or compensate for harm to bycatch species (Box 4). Other criteria include the stage of development or application of each mitigation measure (e.g., research and development, broad use), its relevance for reducing shark catch and mortality, and the strength of evidence to inform predictions of how well a mitigation measure might work. Additional criteria included in the Mitigation Assessment can help inform the feasibility of a given mitigation measure, such as potential for conflict with other at-risk species, degree of deviation from conventional fishing methods required, costs (economic, safety, practicality), reliance on changes to crew behavior, and management capacity.

Box 4. Mitigation Hierarchy Tiers
(Gilman et al. 2022)

Shark bycatch mitigation measures have been characterized into one of four sequential mitigation hierarchy tiers based on how they affect the risk of capture or mortality:

1. **Avoid:** Avoid the risk of capture;
2. **Minimize:** Minimize the risk of capture;
3. **Remediate:** Remediate one or more components of total fishing mortality; and
4. **Offset:** Offset residual bycatch mortalities.

Prioritizing mitigation measures will depend on the specific fishery's objectives. While not all shark catch is unsustainable, if the objective is to reduce catch or mortality (e.g., of threatened or protected species), mitigation measures that completely avoid capture would be considered more effective than those that minimize risk of capture, which are better than those that remediate or offset mortality.
Avoid > Minimize > Remediate > Offset

These suitability criteria are then used to qualitatively determine the potential for each bycatch mitigation measure to effectively reduce catch and/or fishing mortality of shark species across the four shark fishery typologies (Box 2) based on the fate of captured sharks (**Appendix B**).

The Mitigation Assessment provides foundational information and expert judgment to support Steps 3-6 of the SDM process. Mitigation alternatives can be identified and evaluated using this information, with the important caveat that the assessment content is generalized across fisheries and is not intended to be prescriptive for any one fishery. It is also possible that novel mitigation techniques will be developed in the future and they should be considered as well. Thus, the criteria should be carefully reviewed with the local fishery context and new developments in mind, and revised as needed.

2.5 Electronic Monitoring Considerations

Electronic monitoring is a pivotal tool used to support the successful implementation of mitigation measures that require at-sea monitoring, and also provides information needed to ensure compliance with required mitigation measures and address many science data gaps (Brown et al., 2021).

Across the 37 shark bycatch mitigation measures in the Mitigation Assessment (**Appendix B**), at-sea independent monitoring was identified as a key compliance and monitoring approach alongside port sampling, vessel monitoring systems (VMS), and/or dockside inspections for all but one measure (limiting number of vessels, which can be sufficiently accomplished using VMS). Given the importance of at-sea independent monitoring for shark bycatch mitigation, The Nature Conservancy, in collaboration with external partners and researchers, reviewed each of the mitigation measures from the mitigation assessment to determine whether EM could be effective as a tool for at-sea independent monitoring and compliance. This process identified 22 of the original 37 mitigation measures that could be effectively monitored with EM (referred to as EM-enabled mitigation measures; **Appendix B**). We note that EM is not the *only* appropriate approach for monitoring and compliance across these 22 interventions, but it is the focus of this report.

For each EM-enabled mitigation measure, 12 considerations for EM system design were evaluated (**Appendix C**). Electronic Monitoring Considerations included elements such as camera coverage on deck, continuous recording, crew cooperation, gear configuration, and amount of video review needed to use EM for compliance and monitoring for each of the shark bycatch mitigation measures (defined in Appendix C1). The information in the EM Considerations is foundational to designing monitoring systems and is used primarily in Step 7 of the SDM process. The considerations are based on expert judgment and are not intended to be prescriptive for any one fishery. Monitoring considerations should be carefully reviewed with the local fishery, vessel specifications, and monitoring needs in mind, and revised as needed.

2.6 Decision-Making Context

Structured decision-making is designed to incorporate stakeholder input into complex decisions by encouraging all participants to share their values and perspectives (Runge & Bean, 2020). Involving stakeholders in SDM processes can promote transparency through a shared understanding of which problem or challenge is being addressed and how decisions are being made, potentially resulting in broader acceptance of management actions (Wilson & Arvai, 2011). In the data-limited context of most shark bycatch issues, stakeholders can provide important local knowledge about shark resources, shark bycatch, and the needs of the fishery. Diverse stakeholders representing a range of interests and expertise can also help to ensure that decisions are appropriate to the local fishery context and the needs of the fishing community, which can help build support for solutions to shark bycatch issues.

Decision-makers are typically from the fishery management agency. Decision-makers can frame a decision problem and determine (a) whether the input or buy-in of stakeholders would result in a better decision, and then (b) how stakeholders should be engaged. Depending on the decision context, SDM can be used in a simple desktop manner with just the decision-maker(s) or be designed as an inclusive and participatory process with a range of stakeholders providing input (Box 5).

A 'working group' of key stakeholders and experts can be convened to support and contribute to the SDM process. Depending on the nature of the problem being tackled, stakeholders with different expertise may be needed in the working group. Bycatch mitigation experts, scientists, fishery participants (captains, fishing companies), fishery managers, and other stakeholders would all have valuable input to provide during the decision process. Practitioners with experience in decision science and facilitators may also be needed to support larger stakeholder engagements (Johnson et al., 2015). Typically, a working group would use the Shark Bycatch Mitigation DST to evaluate and recommend mitigation measures; however, the decision-maker would make the final decision.

Box 5. Who needs to be involved?
(Hemming et al., 2021)

It is important to be clear about which problem is being addressed, who has the authority to make a decision, and how stakeholders will be involved. Some questions to consider include:

» What is the nature of the problem we are trying to solve? What are we concerned about or hoping to achieve?

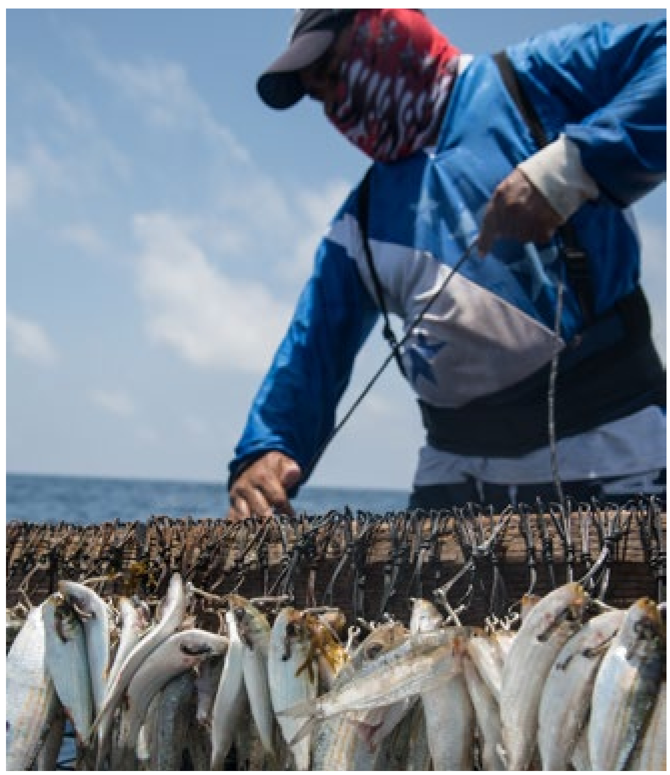
» Are the right people involved in problem identification? Who has a stake in the outcome, and who can influence the outcome? What stakeholder values should be considered?

» How can scientists, policy specialists, fishery participants, and other relevant stakeholders contribute individually and collectively?

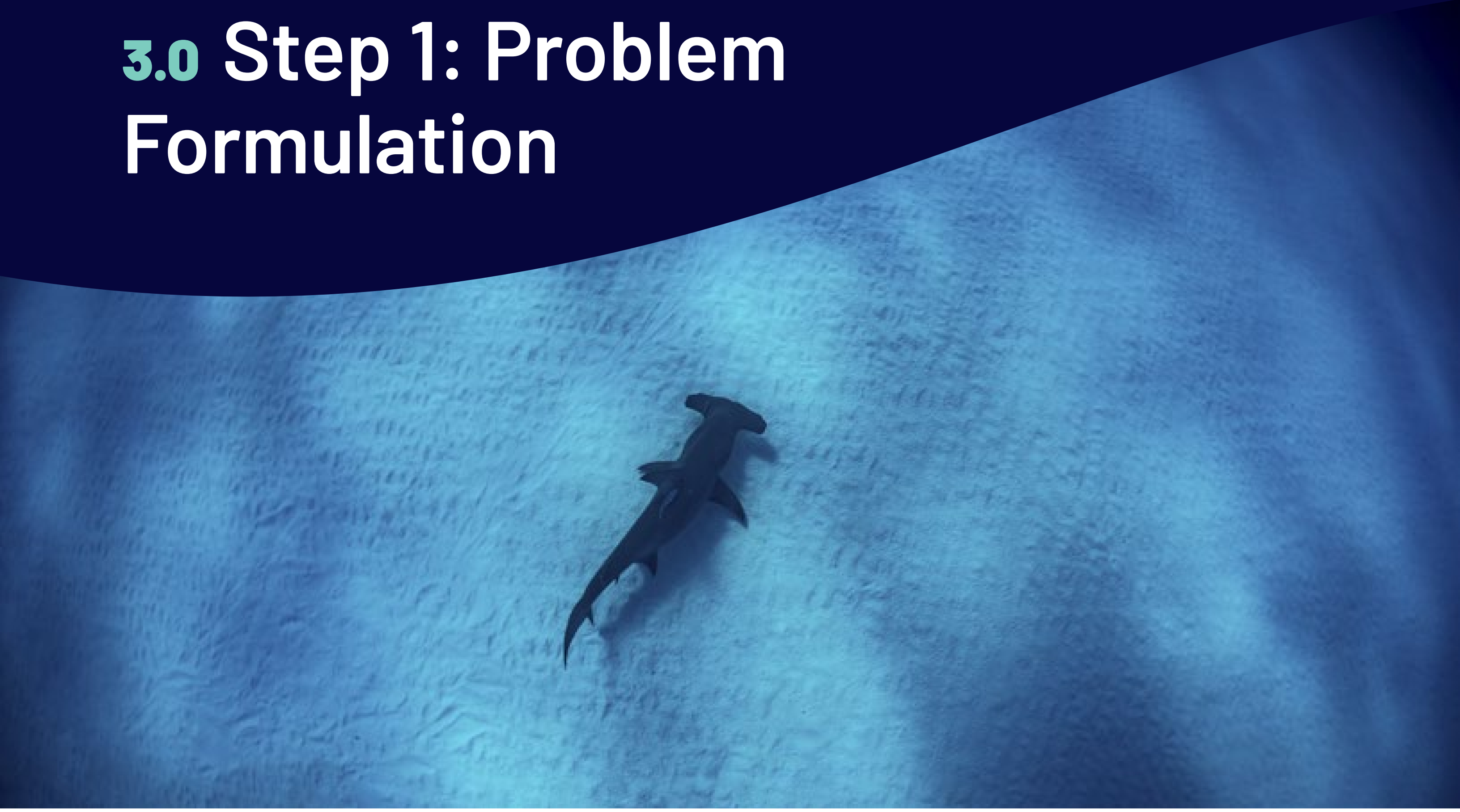
» Who has data, information, and/or local knowledge to understand and address this problem?

» Who has the authority to make the decision? What are the other roles and responsibilities of participants?

» What is the scope (scale and timing) of the decision? Are other decisions linked to this one?



3.0 Step 1: Problem Formulation



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What is the problem we are trying to solve?

Carefully defining and framing the problem that requires a decision is the first step in the SDM process (Conroy & Peterson, 2013; Gregory et al., 2012). What is the problem you want to address, and is it the "right" problem? Is it solvable and does it represent the values of the stakeholders involved?

3.1 Understanding the problem and decision context

Problems should be defined as decisions and carefully framed to guide the rest of the SDM process (Box 6). Identifying and articulating the problem correctly will help to establish a clear foundation for identifying measurable objectives (Step 2) and alternatives (Step 3). Often, these steps are iterative, as potential objectives and alternatives are identified, the precise articulation of the problem statement might change.

Box 6. Problem Formulation
(Conroy & Peterson, 2013; Runge & Converse, 2025)

- Defining problems as decisions.
- Solving the right problem.
- Careful framing of the problem.
- Develop a problem statement that proposes an **action** that we **predict** will lead to **outcomes** that should fulfill **objectives**.
- Revise as needed.

The scientific, socioeconomic and policy contexts also inform how a problem is articulated and helps to frame the decision context to reflect the collective understanding of the problem, values, constraints and opportunities. Considering the broader context in which the decision will be made and who needs to be involved in developing and implementing solutions are key to a successful outcome. Understanding the decision context, limitations, and opportunities will also inform the subsequent steps of the SDM process.

Some key questions to begin to frame the problem are:

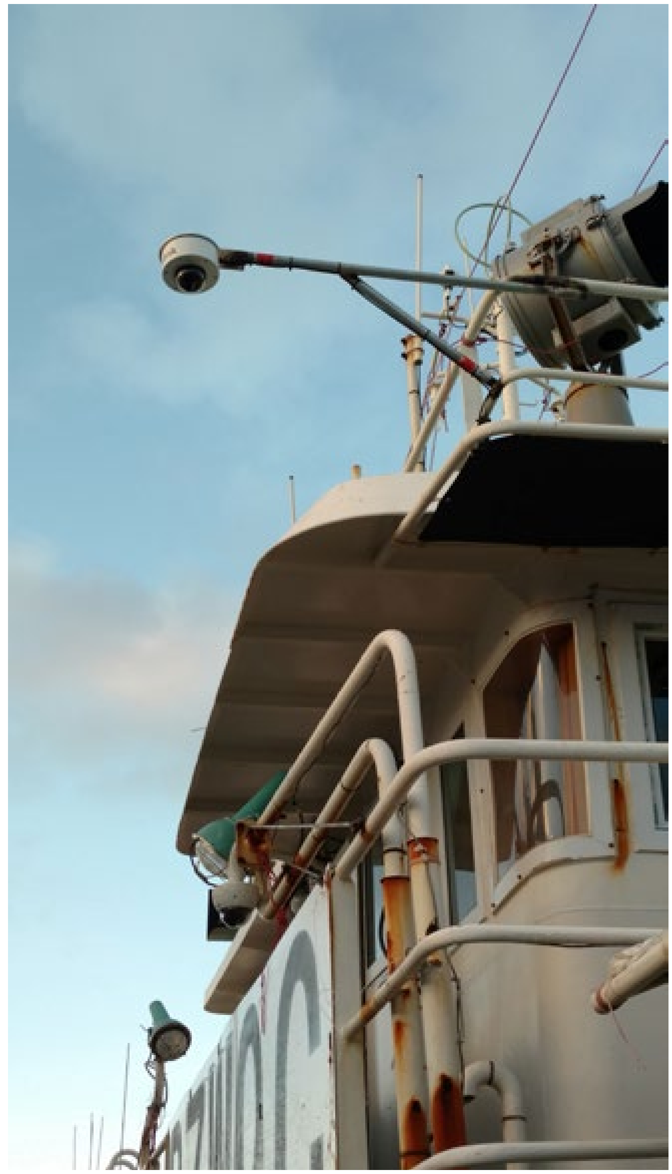
- What is the shark bycatch problem, issue, or challenge? What species are of concern?
- What are the drivers for addressing shark bycatch issues (e.g., economics, regulatory, reputational)?
- What are the regulatory or policy constraints or opportunities?
- What do stakeholders care about?
- What are the logistical and financial constraints?
- What data and information do we have, and what are key data gaps and sources of uncertainty?
- What is within and outside the scope (e.g. spatial-temporal-organizational)?
- What is the decision to be made?

3.2 Identifying and framing solvable shark bycatch problem(s)

It is important to focus on problems that are solvable and that the decision-maker has authority to address. The process of compiling a Fishery Characterization (**Appendix A**) is a key initial step in providing the information needed to understand and identify the shark bycatch problems that need to be addressed, as well as the decision context in which solutions will be identified and implemented. The type of information required to understand which mitigation measures could work includes:

- Fishery characteristics that affect what types of measures could be successfully implemented (e.g., vessel size, gear configuration, fishing effort, target species, seasonality);
- Characteristics of the shark catch that are concerning (e.g., species, catch rates, fate, capture and post-release condition);
- Human/management context in which mitigation measures need to be effectively implemented (e.g., economic and regulatory drivers, socio-cultural aspects, compliance and enforcement); and
- Existing monitoring programs and data that can support the design and evaluation of mitigation measures and help inform data science requirements (e.g., EM, human observers, logbook, port sampling).

The type of shark catch (Box 2) and shark species caught will have a strong influence on the types of mitigation measures that may work, as well as the economic and/or regulatory drivers within the fishery. The catch of endangered, threatened, and protected (ETP) shark species is an important factor given concerns about their population status, special conservation status, and regulatory drivers (e.g. conservation management measures) aimed at reducing interactions with those species.



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It can be challenging to sustainably manage fisheries targeting sharks (Type 1), catching them incidentally and retaining them (Type 2), or finning them (Type 3) as there are strong economic incentives to keep shark catch rates high, especially given the expansion of the shark meat trade in recent years and the continued demand for shark fins (Dent and Clarke, 2015). In cases where shark catch rates are unsustainable, mitigating shark bycatch can also help fisheries achieve sustainability certifications that can unlock greater market access and potential. There are mitigation measures (including market-based strategies) that can work for fisheries that target sharks, but understanding the economic and regulatory constraints and opportunities is an important part of problem formulation.

A large proportion (~54%) of global shark catch is discarded (Feitosa et al., 2025). Even when sharks are not retained (Type 4), there can be significant fishing-associated mortality. Recorded shark catches may only reflect a fraction of total fishing mortality, as mortality associated with discarded shark catch is not reported in most fisheries data. There are a variety of factors that affect whether sharks survive the fishing interaction or are subject to at-vessel mortality or die after they are released (post-release mortality). These include the type of fishing gear, fishing duration, shark handling procedures and the susceptibility of different species to fishing-associated mortality. These factors are important to consider in designing bycatch mitigation measures to avoid or minimize shark catch and also reduce fishing-associated mortality (Tolotti et al., 2015; Gilman et al., 2022; Feitosa et al., 2025).

Understanding the current state of compliance monitoring, extent of existing data, and key data gaps are important aspects of problem formulation and helps to identify and frame 'solvable shark bycatch problems.' While bycatch mitigation is the primary means to achieve the broader goal of reducing fishing impacts on shark populations and is the focus of this DST, scientific data and compliance with required mitigation measures are key supporting elements to ensure bycatch mitigation objectives are achieved and sustained.

Specifically, at this step in the SDM process the working group should determine:

- If there are existing mitigation measures in regulation that are likely sufficient to address bycatch concerns, then the working group could focus on identifying compliance issues and science data gaps that need to be filled (likely with EM) to monitor the performance of those mitigation measures and to assess shark stock status. A formal SDM process is not likely needed to do this.
- If there are insufficient mitigation measures in place to address the shark catch and mortality problems, then the working group should characterize the bycatch problem(s) that needs to be addressed through new actions and continue through the SDM steps to identify preferred mitigation measures.

3.3 Formulating a clear problem statement

A clearly defined problem statement is a critically important first step, and one of the hardest steps in SDM. Generally, the problem needs to be stated in a form that is broad enough to get at the root of the issue and narrow enough to be solvable. It should reflect the values of the stakeholders and the real constraints.

The working group should draft a problem statement that reflects their shared understanding of the shark bycatch problem, values and concerns, decision context, and the type of decision needed. The problem statement should address key guiding questions (Box 7) and clearly address *what decision is needed*, and *what kinds of actions need to be taken*, to address the *concern or requirement* (Conroy & Peterson, 2013; Runge et al., 2017). Some examples of problem statements are provided in Section 10.

Box 7. Problem Statement—guiding questions
(Runge et al., 2017)

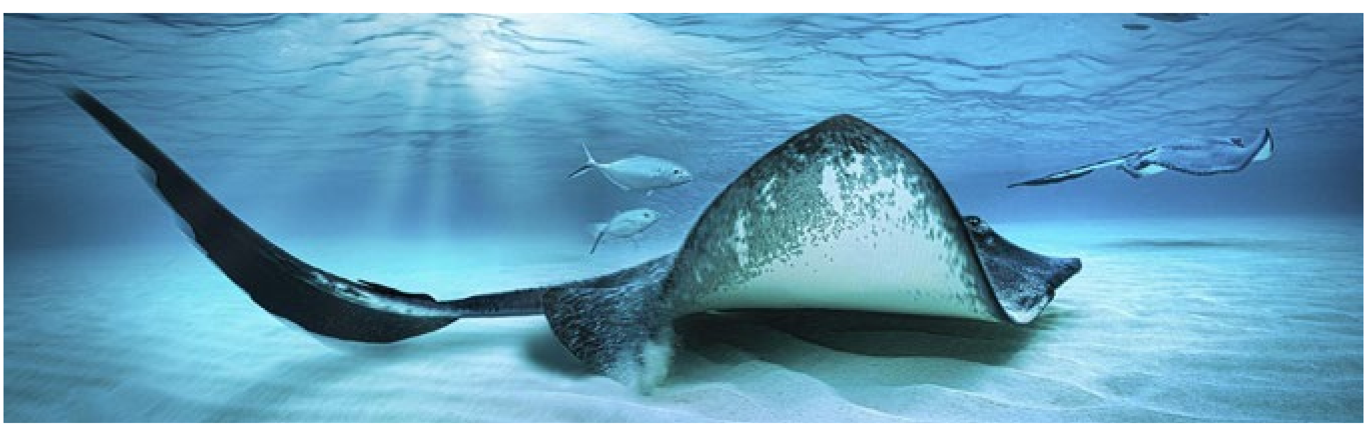
» What is the problem or opportunity?

» What are the real constraints?

» What is within or outside of scope (e.g., spatial-temporal-organization bounds)?

» Who will make the decision?

» What is the decision? What kind of action needs to be taken to address the concern or requirement?



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4.0 Step 2: Setting Clear Objectives

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What do we hope to achieve?

Once the problem has been framed and the stakeholder values identified, the next step in the SDM process (Step 2) is to identify clear objectives, each with a *measurable attribute* that can be used to compare among alternatives to predict how well they might meet that objective. Ultimately, those measurable attributes can be turned into *performance metrics* that can be used in a monitoring program to assess progress toward meeting those objectives.

4.1 What do we hope to achieve? And how do we accomplish that?

Objectives are what you care about and what you hope to achieve. Objectives are specific and quantifiable outcomes that relate directly to the management problem and should also reflect the values of stakeholders and decision-makers (Conroy & Peterson, 2013; Wilson & Arvai, 2011). The types of objectives that are needed depend on the problem(s) being addressed. This process of identifying objectives based on the problem statement may be iterative and help to further redefine the problem statement.

Identifying appropriate objectives can be more difficult than expected as it is also critical to identify and distinguish *fundamental* objectives from *means* objectives (Conroy & Peterson, 2013).

- **Fundamental objectives** are the outcomes the decision-maker wants or needs to achieve and often reflect the values of the stakeholders involved. If we ask the question "Why is that important?" and the answer is "Because that is what we want to achieve" or "Because that is a legal mandate," then that is probably a fundamental objective. The fundamental objective must be under the authority of the decision-maker, controllable, and not so broad as to be unachievable based on available interventions or the decision-maker's authority.
- **Means objectives** are the methods, processes, or means by which fundamental objectives can be achieved, but on their own are not the desired outcome. Asking the question "How do we accomplish that?" can help to identify means objectives. Since means objectives often derive from our conceptual model of how the system works (we need to do *X* in order to achieve *Y*), means objectives can often act as hypotheses for how to achieve the fundamental objective and thus inform potential interventions.

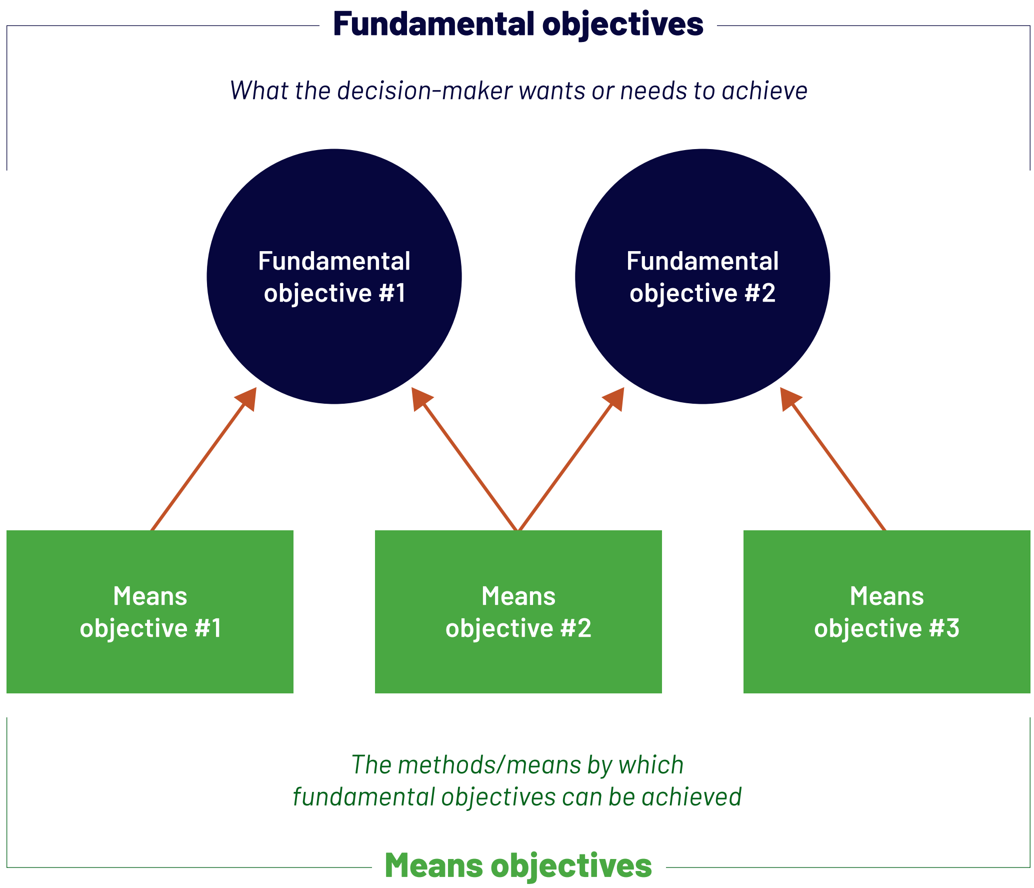

FIGURE 5: Types of Objectives (from Conroy and Peterson 2013)

Brainstorming potential objectives and asking those two guiding questions ("Why is that important?" and "How do we accomplish that?") can guide the mapping of an 'objectives network' to clearly distinguish the relationships between fundamental and means objectives (Figure 5). The result is a rough depiction of how decision-makers think the system works.

4.2 Identifying Shark Bycatch Management Objectives

The working group should develop and refine objectives to address the shark bycatch problem(s). There are important categories of potential objectives that should be considered for shark bycatch management to address the range of important concerns including reducing the catch and/or mortality of ETP shark species and doing that in a way that does not have unacceptable impacts on other vulnerable species or on commercial viability. It may also be necessary to set objectives and take actions to improve enabling conditions in the fishery management regime, such as improving compliance monitoring or surveillance and enforcement, to ensure successful outcomes (Box 8; Gilman et al., 2022).

Box 8. Consider objectives for shark bycatch management that aim to *(Gilman et al. 2022)*

- Reduce catch and/or fishing mortality rates of vulnerable shark species;
- Have acceptable multi-species impacts (including other vulnerable or protected species);
- Support commercial viability (minimize economic, safety, and practicality costs); and
- Include necessary improvements in management (legal, regulatory, monitoring, enforcement, etc.).

A useful step in identifying potential objectives is to have decision-makers and stakeholders articulate their goals or concerns related to shark bycatch. From there, it is possible to refine those potential objectives to be more specific and measurable "SMART" objectives (Box 9). Some examples of this process of moving from general goals and concerns about shark bycatch to potential objectives to SMART objectives with associated performance metrics are provided in Table 1.

Box 9. SMART Objectives

S = Specific—objectives should be specific and narrow.

M = Measurable—objectives that are measurable allow for progress towards achieving them to be assessed.

A = Achievable—objectives should be able to be reasonably accomplished within a certain time frame.

R = Relevant—objectives should align with the values and long-term goals of decision-makers and stakeholders.

T = Time-bound—objectives should have a realistic, but ambitious, end-date.

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TABLE 1: Examples of goals and concerns that help to identify potential objectives. Then those potential objectives can eventually be turned into SMART objectives, with performance metrics that can be monitored and evaluated for success.

Goals and Concerns	Potential Objectives	SMART Objectives
Populations of ETP shark species are declining in the region; unsustainable fishing pressure is a concern.	Implement bycatch mitigation measures to reduce catch or fishing-associated mortality of key ETP shark species.	Employ shark bycatch mitigation measures on 30% of fleet vessels to demonstrate and evaluate effectiveness at reducing catch and mortality of ETP shark species over 2 years. ***Performance Metric:*** *Percent reduction in catch and mortality of ETP species*
Shark bycatch mitigation measures may have adverse impacts on other vulnerable species (e.g., increase catch of sea turtles).	Monitor to ensure that any new mitigation measures implemented do not result in significant increase in catch of other vulnerable species.	Reduce conflict or have no net impact on catch rates of other vulnerable species on the same 30% of vessels testing shark bycatch mitigation measures over 2 years. ***Performance Metric:*** *Catch rates of other vulnerable species, such as sea turtles.*
Sharks are targeted so industry would be negatively impacted by measures that significantly reduce total shark catch.	Provide economic incentives/ opportunities to boost catch of higher value targets and reduce catch of less valuable shark species.	Provide an economic incentive to 20% of the fleet for 3 years to reduce shark catch to evaluate its effectiveness at reducing proportion of sharks vs other target fish in their catch. ***Performance Metric:*** *Ratio of shark to other target species in catch.*

Fundamental objectives to address shark bycatch concerns may include things that the decision-maker wants or needs to achieve such as:

- Reduce catch or catch-associated mortality of ETP shark species.
- Track ETP shark status to ensure sustainability.
- Promote compliance and enforce regulations.

Means objectives would then focus on the means by which the fundamental objective(s) can be achieved. Means objectives may be focused on key elements of a bycatch management program that are needed such as implementation of a fleet-wide EM program for science and compliance, pilot-testing of mitigation measures to identify which work best for that fishery, and necessary improvements in enforcement capacity. Fundamental and means objectives can be mapped out as a network of related objectives (Figure 6).

4.3 Measurable Attributes and Performance Metrics

The working group should also identify *measurable attributes* for each objective that will be used as a common metric to evaluate how each of the potential alternatives (identified in Step 3) is predicted to perform in meeting that objective. Both fundamental and means objectives should be quantifiable and measurable.

Measurable attributes should include:

- A unit of measure (e.g., catch rate of ETP shark species, cost of implementation);
- A preferred direction (e.g., decrease or increase; maximize or minimize).

Performance metrics are the measures that will be used in a monitoring program to evaluate the effectiveness of a decision (e.g., how well did the selected mitigation measure work to achieve the objectives). Measurable attributes are the building blocks of performance metrics. Examples of measurable attributes and associated considerations for monitoring performance are provided in Table 2. Designing a monitoring program with performance metrics to assess progress toward achieving objectives will be described in Step 7.

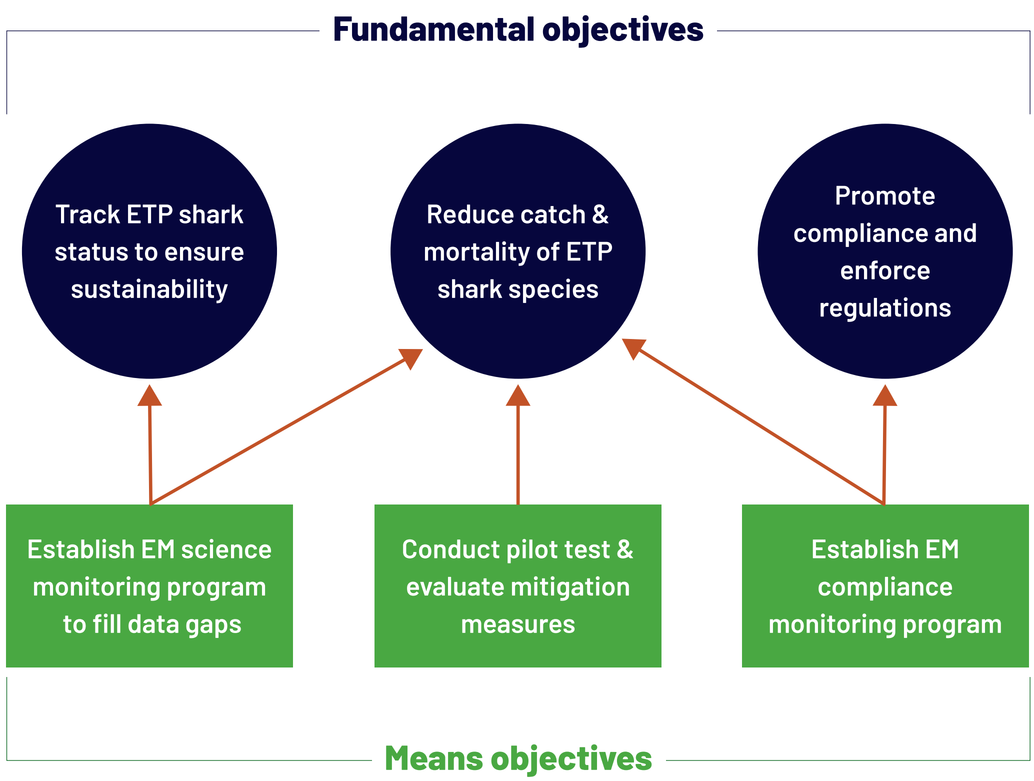

FIGURE 6: Example of a fundamental and means objectives network to address shark bycatch and monitoring problems.

TABLE 2: Examples of measurable attributes and some performance monitoring considerations

Objectives	Measurable Attribute	Preferred Direction	Performance Metrics (and some EM Considerations)
1. Reduce catch of ETP shark species	Catch rates of ETP shark species	Reduced	ETP shark catch rates *(Onboard camera systems; ability to identify shark species;ability to quantify shark catch)*
2. No additional conflict with other vulnerable species	Catch rates of other vulnerable species	Unchanged or lower	Other vulnerable species catch rates *(Onboard camera systems; ability to identify vulnerable species; ability to quantify catch of other vulnerable species)*
3. Economic viability	Cost	Minimize	Cost of implementing mitigation measures. Cost of implementing EM, data collection, and analysis.

5.0 Step 3: Identifying Alternatives

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What could we do?

Step 3 in the SDM process is focused on identifying alternatives—the types of actions that could meet the objectives and address the problem identified in the prior steps.

5.1 Alternatives that will help meet objectives

In the absence of a structured process, there is a tendency to rely on alternative-focused decision making and to choose between two or more options without considering what we value or hope to achieve. The objectives should drive the selection of alternatives to ensure that decision-makers avoid taking actions without clearly understanding why and without an explicit link back to the objectives (Runge & McDonald-Madden, 2018).

Alternatives can be discrete actions or combinations of actions that are predicted to achieve one or more objectives. Alternatives will be evaluated against one another, using a measurable attribute, to assess their predicted performance at meeting the objectives.

Often, alternatives are identified based on prior efforts and an understanding of how the interventions might work, as well as their limitations and benefits. Thinking 'outside the box' to identify new and creative alternatives, or combinations of alternatives, for achieving the objectives can help to challenge perceived constraints (Runge & McDonald-Madden, 2018). If there is significant uncertainty about potential outcomes of different alternatives, pilot projects that test multiple alternatives in a study designed to provide comparative results can be very helpful; however, this should be done in the context of assessing the value of that new information to inform future decisions (Smith, 2020).

5.2 Identifying appropriate shark bycatch mitigation alternatives

The working group should identify the subset of shark bycatch mitigation alternatives that could meet one or more objectives and are appropriate for the fishery and decision context. Those alternatives will be further evaluated through Steps 4-6. While shark bycatch mitigation alternatives are the focus of this DST and decision analysis, it is important to note that the working group could also consider recommending other types of actions that address means objectives or enabling conditions (e.g. an improved legal or regulatory framework, enhanced surveillance and enforcement program, or research that supports effective shark bycatch management).

How do we know if we have enough information to select appropriate mitigation measures and take action? Many bycatch mitigation measures have been used widely, have well-documented effectiveness, and may be appropriate for the fishery under consideration without requiring new information to support implementation. Other mitigation measures may require location and fishery specific information to be implemented successfully (e.g., spatial closures to protect nursery areas or shark catch hotspots may require spatial data). Since many fisheries require a combination of different types of mitigation measures to address shark bycatch, it is likely there are some effective measures that can be implemented early on, even in data-limited contexts, while additional data are being collected to support other measures.

Using the information in the Mitigation Assessment (**Appendix B**), the working group can identify mitigation measures that could work to achieve objectives by considering whether the mitigation measures:

- are appropriate to the type of gear used in the fishery,
- have potential to achieve objectives given shark catch typology of the fishery (e.g., ranked medium or high for the relevant shark catch typology),
- can be enabled by EM systems (or if not EM-relevant, are considered appropriate by working group to further evaluate), and
- are appropriate for the location and fishery, based on the expertise of the working group.

The Mitigation Assessment should be used as a guide, augmented with working group knowledge of the local fishery, to identify a subset of mitigation measures that warrant further evaluation (Table 3). In addition to the Mitigation Assessment, there are other resources that can help to identify potential mitigation measures, such as the Bycatch Management Information System.

TABLE 3: An example of how to filter and use the information in the Mitigation Assessment (Appendix B) and working group knowledge to identify a subset of mitigation alternatives to include for further evaluation for a longline fishery that discards sharks (shark typology 4).

Mitigation Measure	Gear-specific	Shark Typology 4 Potential	EM-relevant?	Location and Fishery Appropriate?*	Include for further evaluation?*
1	Longline	High	Yes	Yes	Yes
2	Longline	Medium	Yes	Yes	Yes
3	Longline	Low	Yes	Maybe	No
4	Longline	High	No	Yes	Yes

**based on working group knowledge*

6.0 Step 4: Predicting Consequences

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What are the predicted outcomes of different alternatives and how will they meet objectives?

Step 4 in the SDM process is to predict, to the best extent possible given data limitations and uncertainty, how well each alternative will perform to meet objectives. Alternatives are then compared with one another to evaluate which alternative (or combinations of alternatives) would best achieve the objectives.

6.1 Predicting consequences of different actions

To predict how well each alternative would meet the objectives, we need to:

- Understand the consequences of different alternatives in terms of the objectives.
- Use a common metric across an objective to compare alternatives.
- Use quantitative or qualitative models and/or expert judgment to predict consequences.
- Incorporate uncertainty.

A consequence table links each alternative (or combinations of alternatives) to the objectives (Conroy and Peterson, 2013; Runge et al., 2017). The consequence table summarizes the predicted consequences for each alternative using a common metric within an objective to allow for comparison across multiple alternatives and multiple objectives (Table 4). If we select alternative X, how will it help to achieve objective Y? And how certain are we of that outcome?

TABLE 4: A consequence table links objectives and alternatives. For each objective, a measurable attribute (and desired direction) allows for comparison of how well each alternative is predicted to meet that objective. The table can include as many objectives and alternatives, or combinations of alternatives, as needed (adapted from Runge et al. 2017).

Objective	Measurable Attribute (units)	Desired Direction	Alternative 1	Alternative 2	Alternative 3
Objective 1	A common metric that can be used to compare how well each alternative will meet Objective 1	Increase, decrease, maximize, minimize	Predicted outcome for Alternative 1 to meet Objective 1	Predicted outcome for Alternative 2 to meet Objective 1	Predicted outcome for Alternative 3 to meet Objective 1
Objective 2	A common metric that can be used to compare how well each alternative will meet Objective 2	Increase, decrease, maximize, minimize	Predicted outcome for Alternative 1 to meet Objective 2	Predicted outcome for Alternative 2 to meet Objective 2	Predicted outcome for Alternative 3 to meet Objective 2

The predictions in the consequence table can be qualitative or quantitative, and can be based on scientific literature, expert input, and/or more rigorous quantitative models (Conroy & Peterson, 2013; Runge & McDonald-Madden, 2018). Sources of uncertainty and risks should be identified and included in the predictions if they are determined to be important to consider. For example, if a mitigation measure is not broadly used, there is limited evidence for its effectiveness, or it carries significant risks, then these factors should be incorporated into the analysis by using criteria that explicitly highlight those factors (e.g., strength of evidence, safety risks). Predictions that carry high uncertainty or risk should be identified so the decision-maker has the information they need to make an informed decision.

A variety of other methods can be used to evaluate consequences. A scoring or ranking system can be used to compare alternatives across multiple objectives in a semi-quantitative manner.

In addition to consequence tables, other methods include conceptual models, evidence synthesis, management strategy evaluation, quantitative models, spatial analysis, and structured expert elucidation (Hemming et al., 2021).

Sometimes multiple objectives may be in conflict with one another or they may differ in their importance to stakeholders and decision-makers; these types of trade-offs will be evaluated in Step 5.

6.2 Evaluating shark bycatch mitigation alternatives

To evaluate shark bycatch mitigation alternatives, the working group can use the Mitigation Assessment (Appendix B) to *identify criteria that provide predictions for how well the alternatives will meet objectives.* These are general predictions for many attributes based on literature review and expert judgment and there may be more fishery-specific local knowledge or information that the working group has that should augment or replace the information from the Mitigation Assessment. There may also be fishery-specific data (e.g., logbooks) that could inform quantitative predictive models of how well different mitigation measures might perform against objectives.

Which criteria from the Mitigation Assessment to use depends on the objectives. For example, if there are objectives focused on reducing ETP shark catch, reducing fishing-associated shark mortality, minimizing additional conflict with other vulnerable species, and minimizing costs to support commercial viability, the following Mitigation Assessment criteria could be used by the working group to inform qualitative predictions for how well each mitigation measure may perform:

- **Mitigation hierarchy tier** (Avoid / Minimize / Remediate / Offset)—generally, an alternative that avoids or minimizes catch would be more effective than those that remediate or offset mortality (Box 4).
- **Application** (Broad use / A few fisheries / Preliminary trials / R&D / Unknown)—generally, a mitigation measure in broad use with known performance would be better (more certainty) than a measure in early stages of development.
- **Reduce shark catch rate**—(Yes / No) measures that have been shown to reduce shark catch would be predicted to perform better than those that have not.
- **Reduce shark fishing mortality rate**– (Yes / No) measures that have been shown to reduce shark fishing mortality would be predicted to perform better than those that have not.
- **Strength of evidence**—(High / Medium / Low) measures with strong evidence supporting their effectiveness would be predicted to perform better than those that have limited evidence and could help to address some aspects of uncertainty.
- **Potential for conflict with other vulnerable species**—(High / Medium / Low) measures with low potential for conflict would be predicted to be more effective at meeting this objective.
- **Economic costs**—(High / Medium / Low) measures that are more cost-effective would be better at minimizing costs.

In this example, the working group would use select criteria from the Mitigation Assessment and revise them as needed based on their local knowledge to make predictions about the ability of different alternative mitigation measures to address the example objectives (Table 5). If an alternative is a combination of multiple measures, then predictions will need to be made based on how the individual measures might perform together. A stoplight (red/yellow/green) system or simple scoring system can be used to compare alternatives and help elucidate better alternatives as shown in the case studies in Section 10.

TABLE 5: An example consequences table for evaluating shark bycatch mitigation alternatives based on predicting consequences towards achieving objectives.

Objectives	Measurable attribute (Desired Direction)	Alternative 1	Alternative 2	Alternative 3	Alternative 1 & 3
	Mitigation Hierarchy Tier (Avoid)	Avoid	Remediate	Minimize	Avoid + Minimize
	Application (broad use)	Broad use	A few fisheries	Unknown	Broad use + Unknown
1. Reduce shark catch & mortality	Shark catch rate (decrease)	Yes	No	Yes	Yes
1. Reduce ETP shark catch & mortality	Shark mortality rate (decrease)	No	Yes	No	No
1 & 2. Reduce shark catch & mortality	Strength of evidence (High)	High	High	Medium	Medium-High
2. Minimize conflict with other vulnerable species	Potential for conflict with other vulnerable species (Low)	Low	Medium	Medium	Low-Medium
3. Minimize costs	Costs (Low $)	High	Medium	Medium	High

7.0 Step 5: Evaluating Trade Offs

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What are the tradeoffs among objectives and alternatives?

Once predicted consequences have been evaluated, Step 5 in the SDM process is to evaluate trade-offs among objectives, as well as risks, sources of uncertainty, and other considerations relevant to the decision.

7.1 Evaluating trade offs

At this stage in the process, it is necessary to determine if there are alternatives (or combinations of alternatives) that would address all the objectives or if there needs to be some evaluation of tradeoffs between or among objectives. If some objectives are more important than others, the alternatives that best address those objectives might be the preferred option. This step is ultimately a values-based decision and requires the working group to prioritize among objectives.

This is also the time to address risks associated with different alternatives to determine if those risks are acceptable to the decision-maker given their risk-tolerance. It is also important to identify the main sources of uncertainty that need to be acknowledged, and perhaps addressed. Sometimes designing pilot projects to test mitigation measures before full-fleet implementation is a useful means of reducing uncertainty and evaluating risks. Additionally, there may be logistical, financial, and regulatory constraints or concerns about feasibility that need to be considered to ensure that the alternatives are implementable (Box 10). Together, these tradeoffs and considerations may make some alternatives more or less preferable.

Box 10. Some key questions when evaluating tradeoffs

- Are all the objectives co-equal or are some more important than others? Are trade-offs between objectives needed?
- Are there combinations of alternatives that will better achieve desired outcomes (compared to either alternative on its own)?
- How does the 'no-action' alternative compare to alternatives that involve taking action? (e.g., what is the risk of doing nothing?)
- What are the risks and uncertainties associated with each alternative? Are they acceptable to the decision-maker?
- Are there logistical, financial, or regulatory constraints to be considered that may affect the feasibility of implementation?
- Are there other important factors to consider?

Different types of decisions might require different analytical approaches to evaluate trade-offs. For decision problems with a single primary objective, evaluating across alternatives to determine which single alternative or combination of alternatives best meets that objective is fairly straightforward but may depend on the degree of certainty in the predictive outcomes.

Assessing trade-offs across multiple (and potentially competing) objectives is a more complex type of decision. In these cases, it may be necessary to reduce gains for some objectives in order to better meet another, perhaps more important or necessary, objective. If there are some objectives that are more important to stakeholders, a weighting system can be added to the scoring system described in Step 4 to weight the scores of more important objectives.

It can be difficult for decision makers to evaluate trade-offs across more than a couple of objectives without assistance, especially in more data-rich contexts. In these cases, there are decision science approaches that can assist decision makers with evaluating trade-offs in a transparent manner (Box 11). More complex semi-quantitative models or investing in additional information can be helpful to improve predictions of consequences to inform the analysis of trade-offs.

Box 11. Evaluating tradeoffs

Many decisions involve multiple, and potentially conflicting, objectives and evaluating tradeoffs can be difficult. Weighting of objectives based on stakeholder values can help to identify tradeoffs. Sometimes tradeoffs can be resolved by identifying a combination of alternatives to better meet the objectives and resolve conflicts. If tradeoffs are hard to navigate, then Multi-Criteria Decision Analysis, cost-benefit analysis, multi-objective programming, management strategy evaluation, or other decision science tools may be needed to identify preferred alternative(s) (Conroy and Peterson, 2013; Hemming et al., 2021).

7.2 Tradeoffs and other considerations for shark bycatch mitigation

The working group will need to determine if some shark bycatch mitigation objectives are more important than others and whether tradeoffs are necessary. There may be regulatory requirements, for example to reduce catch of ETP species, that must be met and require alternatives that have a high likelihood of achieving that objective. In that case, weighting those alternatives higher may be important to identify preferred alternatives.

The feasibility of implementing different shark bycatch mitigation measures is also important and can be a deciding factor at this step in the process. The Mitigation Assessment (Appendix B) includes a qualitative assessment of some other considerations that affect feasibility and may be important to evaluate:

- Practicality costs;
- Safety costs;
- Deviation from conventional methods;
- Relies on changes in crew behavior; and
- Requirement for strong management capacity (i.e., via improved management capacity).

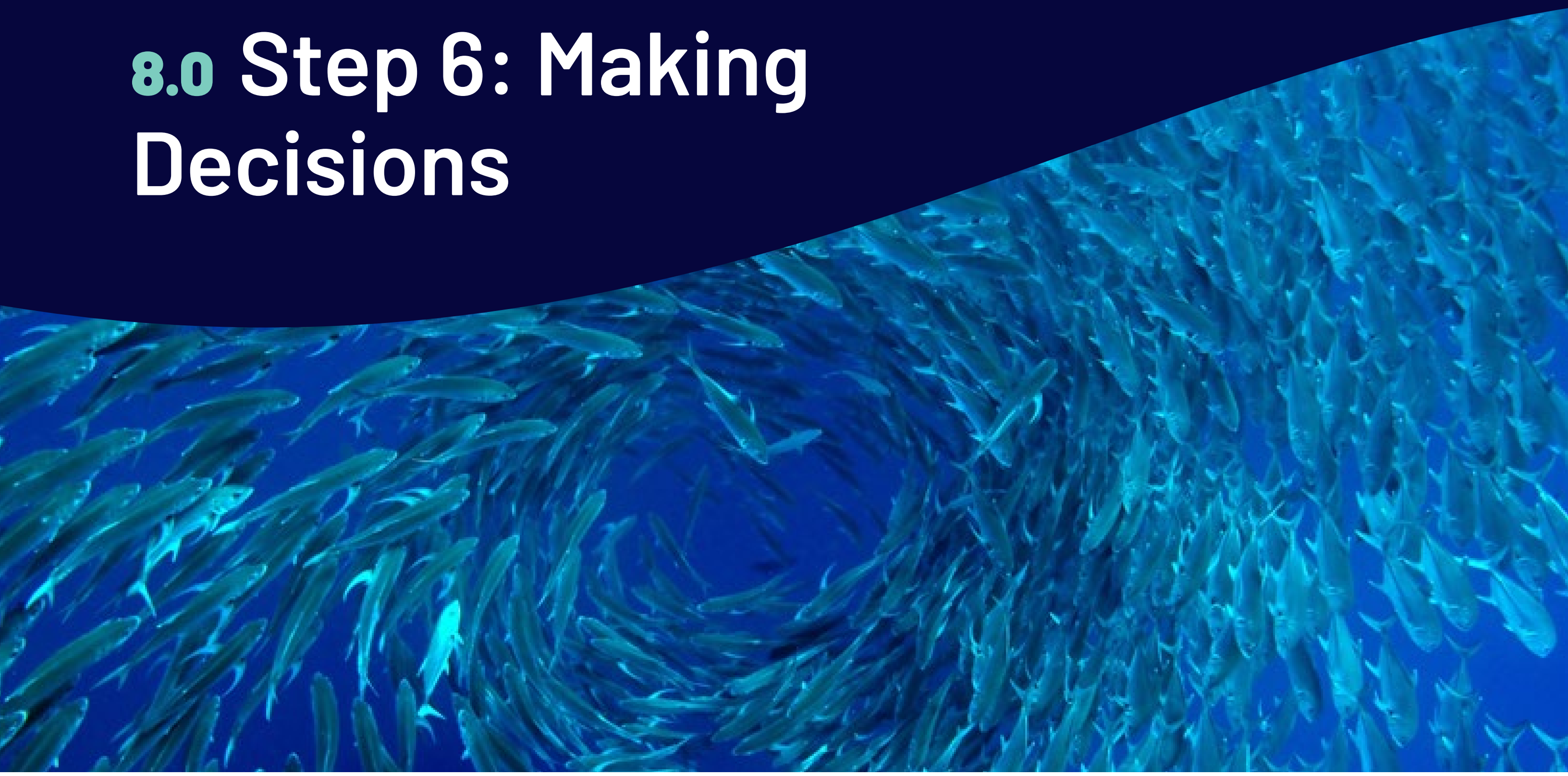
At this stage, it is very important to consider the fishery and local context to identify other considerations and constraints that could affect the successful implementation of mitigation measures being evaluated. For example, there may be socioeconomic or cultural considerations that affect the local, regional and/or national support for different mitigation measures or a focus on specific shark species. There may be concerns about enforcement of and compliance with some shark bycatch mitigation measures that may constrain their effectiveness (e.g., if full EM review is required for effective monitoring for compliance, but existing EM systems are used for catch auditing with no available funding to support expanding analysis and review). Some mitigation measures may be better aligned with policy priorities (e.g., economic development, conservation goals, etc.) than other identified suitable mitigation measures. All of these other considerations can be added to the bottom of the consequence table and evaluated qualitatively or semi-quantitatively to further differentiate the alternatives and evaluate tradeoffs (Table 6).

The simple stoplight or scoring system used in Step 4 can be expanded on in this step to incorporate these other considerations and help identify preferred alternatives. The scores of more important objectives or considerations can be weighted to reflect needed tradeoffs. Based on the information in Tables 5 and 6, the working group should briefly summarize how well each alternative would be expected to meet objectives, as well as any concerns or risks that should inform the decision.

TABLE 6: Adding additional considerations from the Mitigation Assessment and working group knowledge. The combination of the sum score from Step 4 and these additional considerations can help the working group rank alternatives from best to worst.

Other Considerations	Desired Direction	Alternative 1	Alternative 2	Alternative 3	Alternative 1 & 3
Sum score from Step 4					
Practicality costs	Low	Low	High	Medium	Low-Medium
Safety costs	Low	Medium	Medium	Low	Medium -Low
Deviation from conventional methods	Low	Low	Medium	Low	Low
Relies on changes in crew behavior	No	Yes	Yes	No	Yes, in part
Other fishery specific considerations, as determined by working group...					

8.0 Step 6: Making Decisions



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What should we do to best achieve our objectives?

Step 6 is the decision-making step where the 'best' alternative (or combination of alternatives) is selected, given our current understanding of the *consequences, tradeoffs, risks and uncertainty* of each alternative.

8.1 Making informed decisions in an adaptive management context

The evaluation of consequences and tradeoffs leads to identification of alternatives that are predicted to be successful at achieving the desired objectives. Scoring, rankings and weightings used in prior steps to compare across objectives and to identify preferred alternatives are helpful but it can still be challenging to select the 'best' option. One approach is to simplify the problem as much as possible by prioritizing or reducing the number of objectives; this can sometimes be achieved by combining objectives, removing objectives where alternatives had the same predicted outcome, or transforming some objectives to constraints (Runge & Converse, 2025).

Making decisions requires tackling uncertainty and determining an acceptable level of risk, which will depend on the decision-maker's risk tolerance and the decision context (Box 12). While uncertainty should be accounted for, uncertainty does not necessarily have to be resolved in order to make informed decisions (Conroy & Peterson, 2013). Decisions can be made to take action even in the face of high uncertainty, if potential risks are deemed acceptable or able to be mitigated.

When is more information needed? Collecting more information can help to reduce uncertainty, but it should not be used to delay actions unless the new information will substantially improve the outcomes or change the decision (Moore and Runge, 2012). Understanding when new information is pivotal and would significantly improve predictions and inform better decisions will help to inform when to invest in research or monitoring, instead of more direct actions (Runge, 2020; Runge & McDonald-Madden, 2018; Runge et al., 2011). Conducting pilot projects and small-scale actions as a first step can help to fill data gaps, reduce uncertainty, and inform learning.

While making informed decisions does not guarantee good outcomes, it should improve the chances of success and should inform learning (Bottrill et al., 2008; Conroy & Peterson, 2013). Decisions can be designed as experiments in an adaptive management context where an ongoing cycle of learning and adapting over time is part of a broader goal, especially in the face of uncertainty and changing conditions (Walters, 2002; Edmondson & Fanning, 2022).

Box 12. Address risks and uncertainty when making a decision

» Consider the risks associated with each alternative and the risk tolerance of the decision-maker;

» Address uncertainty and identify if more information is required before a decision is made; and

» Design actions as experiments that can promote learning and adaptive management.

8.2 Making shark bycatch mitigation decisions

Even in the data-limited context of shark bycatch mitigation, the working group can select 'best' shark bycatch mitigation alternatives using the available information and expert judgment. Some key steps include:

- prioritizing objectives,
- using scoring, rankings, weightings to evaluate consequences and tradeoffs,
- assessing uncertainty and risks, and
- addressing location and fishery specific considerations.

The working group can use ranked-choice voting or other tools to elucidate preferences and identify preferred alternatives and make management recommendations across all shark species or for very specific shark species (e.g., ETP species, culturally important species). Many shark bycatch mitigation strategies may also positively benefit other at-risk species, which can be captured through quantitative or qualitative weighting to prioritize their suitability in some contexts. At the end of the process, the decision-maker is responsible for selecting the alternative(s) to be implemented, but ideally that would be a decision informed by the working group's efforts to weigh tradeoffs and other considerations.

The decision should be documented to provide transparency and communicate to key stakeholders about the problem being addressed, the decision that was made and why, any risks or uncertainties that need to be acknowledged, and the enabling conditions that are needed to ensure the decision will be effectively implemented to achieve desired outcomes. The summaries of hypothetical case studies (Section 10), that briefly summarize each step in the SDM process, are one example format. A worksheet and blank templates for an SDM process are provided in Appendix D.

8.3 Enabling conditions to support shark bycatch mitigation decisions

As a decision is being made, it will also be important to ensure that the enabling conditions are in place to support the implementation of the alternatives selected. Making a decision on the best bycatch mitigation alternatives will depend, to some extent, on enabling conditions and constraints such as the:

- Associated policy and regulatory context, including RMFO, national, and local regulations;
- Management agency capacity and resources;
- Capacity and interest by partner organizations and funders;
- Importance of the problem to stakeholders;
- Socio-economic impacts of addressing the shark bycatch issues;
- Feasibility of actions (e.g., logistics, accessibility, scalability); and
- Available resources for monitoring and enforcement.

While these constraints should be built into the process and considered at earlier stages, the selected alternative at the decision step should address the underlying constraints and opportunities. If needed, means objectives that aim to address constraints or necessary enabling conditions can be identified and added into the process in an iterative manner to ensure that selected management actions will have a high chance of successful outcomes. The SDM process should help to elucidate constraints and identify ways to potentially overcome existing constraints by bringing a broad array of stakeholders and policy makers together around what needs to happen and the resources to ensure that the decision can be fully implemented.

9.0 Step: 7 Act, Monitor, and Learn

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Can we design interventions and monitoring to advance learning and adaptive management?

Taking action by implementing the preferred action(s) and incorporating monitoring and learning to advance adaptive management is the last step of the SDM approach (Step 7). EM plays a fundamental role in this step by facilitating the verification required to ensure that any given shark bycatch mitigation measure selected during the SDM process is being properly implemented and is achieving the desired outcome for the fishery.

9.1 Implementation Plan

An implementation plan should clearly articulate the overarching goal, objectives, action(s) selected, and the implementation activities required to deliver successful and transparent mitigation measures. Outreach and training for various fisheries stakeholders, including skippers, fishers and vessel owners who are responsible for the action(s) will be critical to ensuring participants have the resources and support required to effectively implement the selected mitigation measures (Box 13). Ideally, the implementation plan for the mitigation measures selected in Step 6 can be designed as a pilot with targeted performance monitoring to promote learning and reduce uncertainty and risks in future decisions. Tracking implementation challenges can help to advance understanding of feasibility, costs, and logistical constraints that could inform future decisions.

Box 13. Building Training Frameworks for Effective Implementation

Integrating training procedures into the frameworks of EM program design and sustainable fisheries management plans is crucial for ensuring that objectives are being met. Providing training for fishers, captains, and vessel owners on the use of EM systems and the implementation of bycatch mitigation measures (including the use of best handling and release practices) ensures that those tasked with implementing mitigation measures have the resources required to do so effectively and ultimately achieve desired program objectives.

Case Study: French Polynesia Bycatch Training

At the end of 2022, TNC completed an EM pilot project in the French Polynesia tuna longline fleet to explore whether or not proper BHRPs for ETP species were being used successfully. Reviewing EM footage revealed that BHRPs were not being followed. Captains and crew were trained on BHRPs and the BHRP guidelines were posted onboard the vessels to ensure crew had access to them even after the training. An example of these guidelines is included below. Reviewing EM footage after the training showed crew members were successfully implementing BHRPs for ETP species, like sharks and rays.

9.2 Monitoring plan and the role of EM

On-the-water monitoring via EM supports flexible decision-making and can allow for modifying existing mitigation measures or implementing new measures if new EM data collected through the implementation phase indicate that the mitigation measures are not meeting the objectives (Figure 7). Measurable attributes from Step 2 should be turned into performance monitoring metrics that reflect the objectives the decision is aiming to achieve. Interventions can be designed as pilot projects with monitoring designed to evaluate certain metrics including:

- Implementation monitoring—Did the intervention 'work'? (e.g. Was it feasible? Was there compliance?)
- Performance monitoring—Did the intervention have the desired effect on fundamental objectives and their associated performance metrics? (e.g. reduce shark bycatch and/or mortality, meet cost constraints, etc.).

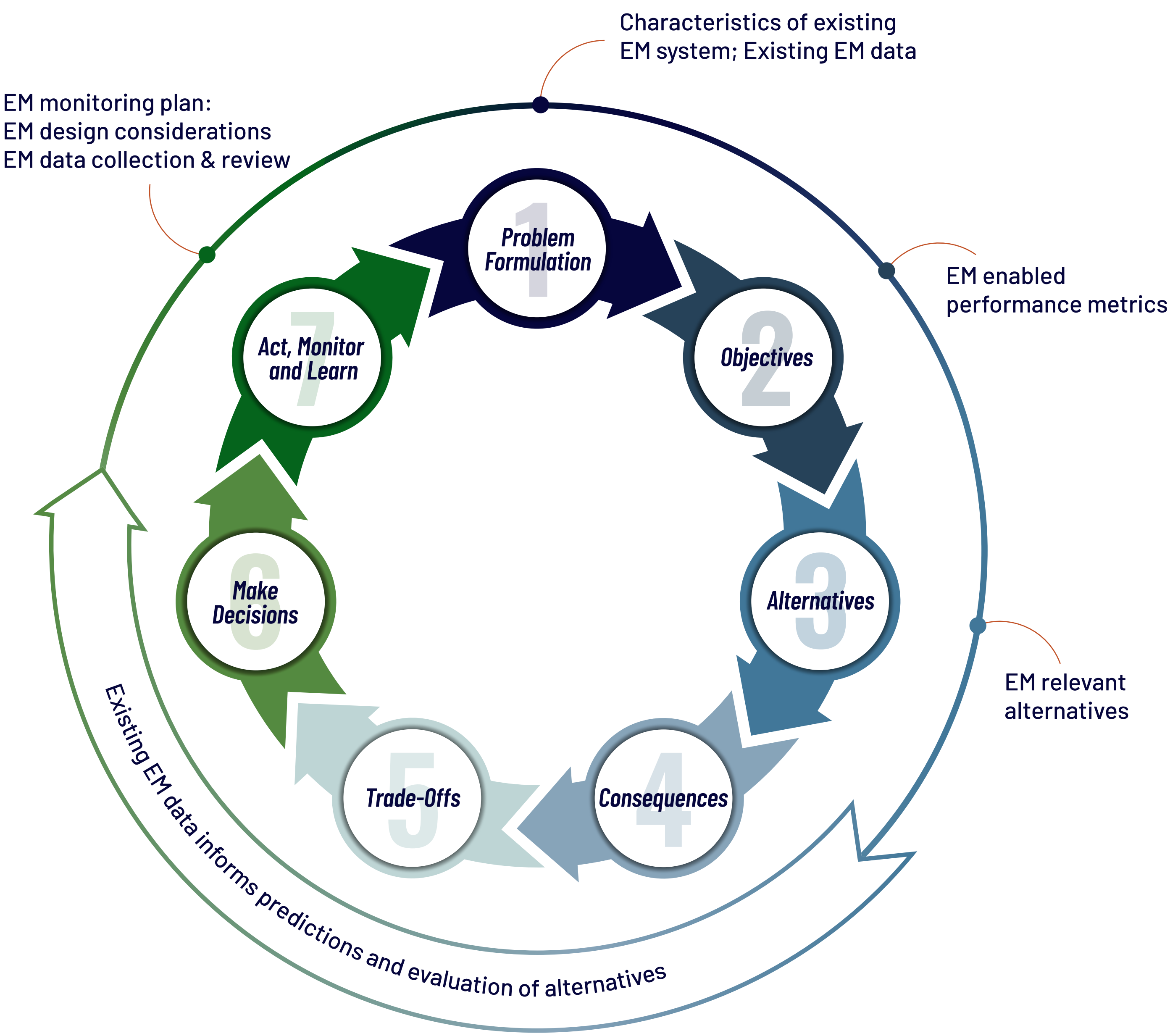

FIGURE 7: EM supports the decision-making process

Developing a monitoring plan will help to identify resources needed, timelines for data collection, requirements for the amount of data to be reviewed and potential risks. A key aspect is that the monitoring program must be linked explicitly to the project objectives to inform learning and adaptive management. Monitoring of criteria explicitly identified in stakeholder processes is necessary to gain support for adaptive changes to the implementation approach, if they are needed. In addition to monitoring the implemented shark bycatch mitigation measures, EM plays a key role in supporting science and compliance needs (Box 14). While this DST is not intended to help stakeholders design their own EM programs, it can certainly help inform how they manage and collect data on shark bycatch.

Box 14. Electronic monitoring is key to filling key science and compliance data gaps

Electronic monitoring is pivotal for providing cost-effective fisheries data. Some types of shark bycatch-related data that EM can provide include:

- **Science:** fishing effort, shark catch, spatial and temporal effort, retained and discarded catch, length-frequency, at-vessel mortality, and interactions with other protected species.
- **Compliance:** vessel accountability, compliance with mitigation measures at-sea (including compliance with best handling and release practices), crew behavior requirements, and locational information.

When implementing shark bycatch mitigation measures into EM program design, it's important to understand the key considerations required for appropriately tracking those measures for science and compliance purposes. More information on EM considerations is included in **Appendix C**. Additional information for stakeholders looking to develop an EM program can be found in Box 15.

Box 15. Support for EM Program

There are several publicly available resources that can support EM program and data standard design, including:

- **TNC's EM Program Toolkit**—Guidance developed by TNC for designing and implementing EM programs
- **SFP's Moving Electronic Monitoring Forward**—A technical report designed by the Sustainable Fisheries Partnership (SFP) to support the design, implementation and performance of a regulated EM program
- **ISSF's Electronic Monitoring Systems & Sustainable Tuna Fishing**—A factsheet developed by the International Seafood Sustainability Foundation (ISSF) to help answer questions that tuna vessels and other sustainability stakeholders may have about using EM technology to avoid IUU fishing and collect data for compliance assessments and scientific studies.

9.3 Adaptive management

Fisheries are geographically and compositionally diverse systems that can be quite complex and challenging to manage, especially in the face of regulatory changes and economic drivers. Fisheries experience changes in both regional and national regulatory policies that are often influenced by market-based initiatives or incentives (Box 16). The complexity and uncertainty in fisheries systems often call for a dynamic and adaptive management structure.

Box 16. Economic Incentives for Sustainable Fisheries Management

Economic initiatives that generate market access can be effective ways of driving more sustainable fisheries management. For example, the European Union's (EU) carding system was designed to eliminate IUU fishing and requires all non-EU countries exporting fish to the EU meet strict fisheries management standards. A green card means imports can continue as usual, a yellow card acts as a formal warning to countries that need to reduce IUU fishing in their fleets and a red card effectively bans a country from selling products to the EU. It has been estimated that a yellow or red card can correlate to roughly a 23% or 83% decrease, respectively, in seafood exports from a given country to the EU (Kim and Lim, 2024). This kind of market-based management forces countries to implement and maintain sustainable fisheries management practices to maintain access to EU markets.

Another market-based initiative aimed at eliminating IUU fishing is the Tuna Transparency Pledge (TTP). The TTP is a voluntary global initiative led by TNC encouraging retailers, seafood suppliers, and governments to use their purchasing power to drive transparency in their supply chains. The **TTP aims to achieve 100% on-the-water monitoring (via electronic monitoring and/or human observers) across all industrial tuna fishing vessels by 2027**. As of June 2025, ten of the world's top seafood retailers and suppliers, including Walmart and Thai Union, and six countries have made the pledge—driving a large proportion of downstream actors (i.e., fisheries managers and regulators, vessel owners, etc.) to act in order to maintain critical market access.

By incorporating adaptive management considerations into shark bycatch mitigation implementation plans, decision-makers can avoid stagnant decisions that are costly or time-consuming to implement and are not flexible enough to meet challenges. EM can act as a critical element for adaptive management by enabling stakeholders to build on-the-water monitoring plans and adaptively manage measures accordingly based on reviewed data. By investing in EM and conducting science and compliance monitoring as part of the adaptive management process, it will be possible to:

- Demonstrate the role of EM in shark bycatch management,
- Collect the data needed to adaptively manage the fishery, and
- Build evidence for bycatch mitigation management across gear types and potentially even across other taxa (i.e., rays, sea turtles, seabirds)

In conclusion, Step 7 is fundamental to ensuring that Shark Bycatch Mitigation DST users can implement bycatch mitigation measures under an adaptive management plan that can be tested, reviewed, and iterated as needed based on data collected from EM systems and interactions with regulatory and market-based frameworks. When developing an adaptive management plan, it will be important to consider the following questions:

1. **Test:** How can we collect data to better understand the implications of our decisions (Step 6)? How long should an initial implementation trial last? What are the monitoring needs and considerations to best support adaptive management?
2. **Review:** Are the current decisions making an ecological, financial, or other system change in our fishery? Is the current monitoring set-up providing us with the data needed to meet science and compliance needs in our fishery?
3. **Iterate:** What would we do differently to improve on our decisions if the current measures are not meeting our target objectives? How and when will it be iterated, if needed, and who will be responsible for driving change?

10.0 Hypothetical Case Studies

Hypothetical case studies that reflect real shark bycatch mitigation issues in global tuna fisheries are included below as examples to help illustrate the use of the Shark Bycatch Mitigation DST. Note that these are hypothetical scenarios and do not reflect actual decision processes, stakeholder values, agency priorities or existing projects. The goal is to illustrate how the SDM steps and resources provided can be used to identify shark bycatch mitigation alternatives in a decision process. There are two hypothetical case studies:

Hypothetical Case Study 1—Reducing catch and at-vessel mortality of ETP shark species in a Longline (LL) fishery where sharks are discarded.

Hypothetical Case Study 2—Reducing incidental catch and at-vessel mortality of ETP shark species in a Longline fishery targeting sharks.

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Reducing catch and at-vessel mortality of ETP shark species in a Longline (LL) fishery where sharks are discarded

This is a multiple-objective problem to evaluate trade-offs among objectives to identify the best alternative(s) for reducing incidental catch and fishing-associated mortality of discarded shark species.

Background: This is a hypothetical domestic LL fishery targeting tuna and billfish species, with 75 vessels, averaging 25m in length. Sharks are not retained; sharks are caught incidentally and discarded (shark catch Type 4). The ETP shark species commonly caught in this fishery include oceanic white tip, silky shark, and about 5 other species. There are existing retention bans on all ETP shark species, but currently there is limited monitoring of compliance. Additionally, there are existing requirements for use of circle-shaped hooks. There is a pilot EM project in place on 5 of the 75 vessels. Implementation of a full EM system on all vessels, with a 20% review rate, is underway and should be completed within the year. There are some existing data from the pilot program on shark catch, at-vessel shark fate, and shark bycatch hotspots.

STEP 1 | Problem Formulation: *What is the problem we are trying to solve?*

Values & Concerns: There are concerns about ETP shark population sustainability and a lack of compliance with existing bans and other regulations. There are also concerns about needing to reduce shark interactions and fishing-associated mortality of sharks that are discarded. The managing agency has a good working relationship with the domestic fishing industry and values their input and support for management measures.

Decision Context and Decision Needed: The national management agency is the decision-maker. Guidelines and recommendations from the RFMO are important considerations. Incentives for implementing a full monitoring program come from the Tuna Transparency Pledge (Box 13). A working group of diverse stakeholders is tasked with identifying preferred bycatch mitigation alternatives for the decision-maker to consider to address concerns about shark bycatch.

Problem Statement: What EM-enabled mitigation measures can we implement to reduce incidental shark catch and better manage discards to reduce fishing-associated mortality of ETP sharks?

STEP 2 | Objective Setting: *What do we hope to achieve?*

Fundamental Objective 1: Reduce incidental catch of ETP species by 50% in 3 years by augmenting retention bans with additional EM-enabled mitigation measures.

Fundamental Objective 2: Reduce at-vessel mortality and post-release mortality of ETP shark species by 50% in 3 years.

Fundamental Objective 3: Minimize costs of implementing and monitoring mitigation measures to meet available budget over 3 years.

STEP 3 | Alternatives: *What could we do?*

Potential alternatives that could meet objectives 1 and 2 were identified using the Mitigation Assessment (**Appendix B**). Objective 3 (cost minimization) can be addressed through the process of evaluating mitigation alternatives and tradeoffs. Six mitigation measures were identified as being EM-relevant, appropriate to LL gear, and having medium or high potential for shark catch Type 4 (not retained). The working group determined these six alternatives could work in this specific location and fishery and should be considered further:

A. Require use of monofilament leader only.

B. Ban the use of lazy lines.

C. Use best handling and release practices.

D. Spatial closure of high shark bycatch area (potentially ~20% of fishing grounds).

E. Limit number of vessels or vessel days.

F. Limit duration of fishing operation (tow time).

STEP 4 | Consequences: *What are the predicted outcomes of different alternatives and how will they meet objectives?*

The Mitigation Assessment provides a first approximation for how well each measure would perform to meet objectives based on a variety of criteria. This information was carefully reviewed by the working group based on the local fishery context and used to create a consequence table.

The Mitigation Hierarchy Tiers characterize how these measures act to reduce shark catch and mortality and can be used to help evaluate their effectiveness at achieving objectives 1 and 2. Similarly, the application (stage of development) of the mitigation measure can help to evaluate how well-tested and broadly used the mitigation measure is. A stoplight approach (red/yellow/green) and scoring each attribute was used to elucidate which alternatives may be more favorable.

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Consequence Table: All of the information on the alternatives in this table came from the Mitigation Assessment (Appendix B).

Objectives	Measurable Attribute (desired direction)	Alt. A Mono-filament leader	Alt. B Ban lazy line	Alt. C Best handling practices	Alt. D Spatial closure	Alt. E Limit vessels or days	Alt. F Limit tow time
	Mitigation Hierarchy Tier (avoid)	Minimize/ remediate	Remediate	Remediate	Avoid	Avoid	Minimize / remediate
	Application (broad use)	Broad use	Unknown	Broad use	Broad use	Broad use	Broad use
1. Reduce catch of ETP species	Shark catch rate (reduce)	Yes	No	No	Yes	Yes	Yes
2. Reduce at-vessel mortality	Shark mortality rate (reduce)	Yes	Yes	Yes	No	No	Yes
1. & 2. Reduce catch and at-vessel mortality	Strength of evidence (High)	High	Low	Medium	Low	High	Low
3. Minimize costs	Costs (Low $)	High	Low	Low	High	High	Medium
Score:		**15**	**11**	**14**	**12**	**14**	**14**

(Scoring: Green = 3, Yellow = 2, Red = 1)

At this point, alternatives A, C, E, and F may be best predicted to meet the objectives based on their score.

STEP 5 | Trade-Offs: *What are the trade-offs among objectives and alternatives?*

The working group discussed tradeoffs and determined that all three objectives are important, but reducing catch and mortality are the priorities as long as costs to the industry can remain acceptable and there is some degree of industry support for the measure. Other important considerations they wanted to evaluate were incorporated into a summary table. Some of the considerations derived from the Mitigation Assessment (Appendix B), while others were fishery-specific and identified by the working group (e.g., fishing industry support for the measure).

Other Considerations: The information on the alternatives in this table comes from the Mitigation Assessment (Appendix B), except for "Industry Support" which was identified and assessed by the working group.

Other Consider-ations	Measurable Attribute (desired direction)	Alt. A Mono-filament leader	Alt. B Ban lazy line	Alt. C Best handling practices	Alt. D Spatial closure	Alt. E Limit vessels or days	Alt. F Limit tow time
Score from Step 4:		**15**	**11**	**14**	**12**	**14**	**14**
Practicality costs	Low	Low	Medium	Medium	Low	Low	Medium
Safety costs	Low	High	Medium	Low	Low	Low	Low
Deviation from conventional methods	Low	High	Medium	Low	High	Low	Medium
Relies on changes in crew behavior	No	No	Yes	Yes	No	No	Yes
Other fishery specific consideration: Industry Support	High	Medium	Medium	High	Low	Low	Medium
Sum Score:		**25**	**20**	**26**	**23**	**27**	**24**

(Scoring: Green = 3, Yellow = 2, Red = 1)

The working group discussed each of the alternatives, their sum score, and associated risks and uncertainties based on their expert knowledge and available scientific literature. At this point, the working group also started to consider whether a combination of alternatives implemented together could be more effective at meeting objectives. Some highlights of their review:

A. **Require use of monofilament leader only**—use of monofilament leader, rather than wire leader, can allow the shark to escape once hooked and potentially result in lower catch per unit effort and fishing-associated mortality and there is good evidence for its effectiveness (e.g. Gilman et al. 2016). This measure results in some costs to the industry (economic and safety costs) and requires a change from conventional methods, yet still has moderate industry support.

B. **Ban the use of lazy lines**—this alternative prohibits attaching sharks to a lazy line off the stern of the vessel temporarily during gear haul-back and thus would require changes in crew behavior. It would not affect shark catch rates and there is limited evidence that it reduces shark mortality rates. There are potential safety concerns about this alternative.

C. **Use best handling and release practices**—proper handling and release of sharks can significantly improve fishing-associated mortality (Hutchinson and Bigelow, 2019; Feitosa et al., 2025). This alternative is also recommended in guidance from the RFMO. It is in broad use and has relatively low costs (economic, practicality, safety). There is also industry support for this measure. While this does require a change in crew behavior as they handle sharks, when crews are properly trained, these practices can reduce fishing-associated mortality.

D. **Spatial closure of high shark bycatch area**—this alternative would create a shark protected area, which if designed appropriately for the shark species and managed effectively could result in benefits to shark populations from reduced fishing pressure (Goetz et al., 2024). Spatial closures can have an economic impact on the fishery and can also result in displaced fishing effort (Jaiteh et al., 2016). At this time, there is no industry support for this measure. Additionally, there is limited spatial-temporal shark catch data to effectively design a shark sanctuary.

E. **Limit number of vessels or vessel days**—limiting vessels or vessel days could reduce shark catch but at a high economic cost to the fishery and there is little industry support for this measure.

F. **Limit duration of fishing operation (tow time)**—there is good evidence that longer tow times can increase shark mortality rates (Ellis et al., 2017). Reducing tow time is a relatively cost-effective and industry-accepted mitigation measure.

STEP 6 | Decision: *What should we do to best achieve our objectives?*

The working group used a ranked voting method to identify their preferred alternatives, then discussed a combination of alternatives that together would better meet objectives and could be feasibly implemented given enabling conditions in the fishery management regime. The working group recommended to the decision-maker that they implement a combination of Alternatives A (use of monofilament leader), C (best handling practices), and F (limit tow time). These three alternatives had relatively low uncertainty and acceptable risks, given the risk tolerance of the decision-maker. The existing enabling conditions were considered sufficient to support these actions.

As new data become available through the EM system, the effectiveness of these measures and the need for additional mitigation can be evaluated. The working group recommends revisiting the Spatial Closure alternative (Alternative D) when those spatially-explicit data are available, with an additional focus on protection of pupping and nursery areas for key species.

STEP 7 | Act, Monitor and Learn: *Can we design interventions and monitoring to advance learning and adaptive management?*

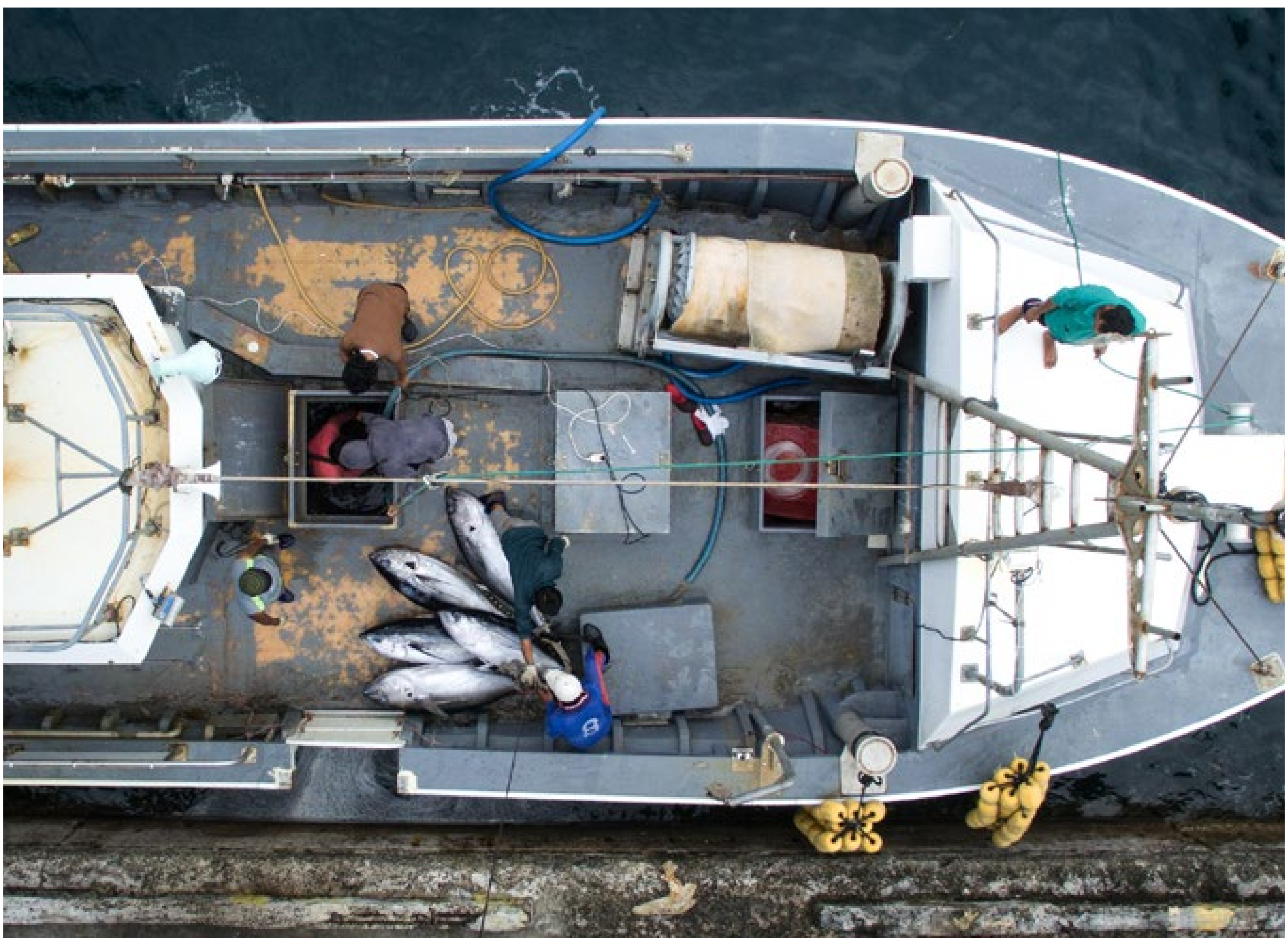
An implementation plan should be developed to identify all the activities and timeline needed to guide implementation of the three alternatives. Monitoring of the performance of these alternatives at reducing shark catch and mortality, as well as monitoring compliance, should be evaluated through the soon-to-be implemented fleet-wide EM system. EM design considerations for these mitigation measures can be found in Appendix C and include:

A. **Require use of monofilament leader only:** full deck coverage, crew cooperation, gear configuration, and new data parameters.

C. **Use best handling and release practices:** full deck coverage, off-deck coverage, crew cooperation, operational procedures, and new data parameters.

F. **Limit duration of fishing operation (tow time):** continuous recording and gear sensors.

As part of an adaptive management approach, the effectiveness of mitigation measures and compliance with mitigation measures should be reviewed regularly and adjustments made as needed to meet objectives.



Reducing incidental catch and at-vessel mortality of ETP shark species in a Longline fishery targeting sharks

This is a multi-objective problem to evaluate trade-offs among objectives to identify the best alternative(s) for reducing incidental catch and fishing-associated mortality of ETP shark species for which there are retention bans in a fishery that targets and retains other species of sharks for local market (Type 1 and 2).

Background: This is a hypothetical domestic LL fishery targeting high value tuna, mahi mahi, and billfish species for the export market. There are 350 vessels, averaging 20m in length. Sharks are also targeted (Type 1), as well as caught incidentally and retained (Type 2) for the local market.

Ten species of ETP sharks are caught in this fishery including oceanic white tip, silky shark, hammerheads and other species. There are existing retention bans on all ETP shark species and there is a full EM system on all vessels, with a 20% review rate. Existing EM data show significant catch and discard of ETP sharks. EM data were used to characterize spatial-temporal patterns of ETP shark catch to identify hot spots, as well as areas with high catch of juvenile/small ETP sharks.

STEP 1 | Problem Formulation: *What is the problem we are trying to solve?*

Values & Concerns: There is concern about ETP shark population sustainability as they are caught in high numbers and discarded, with unknown fate. Since some shark species are important economic targets, especially when high value export fish targets are not abundant, there are concerns about mitigation measures that would have unacceptable economic impacts. Given the existing spatial-temporal catch data, there is pressure on the managing agency to do more spatially-explicit adaptive management of the fishery to meet conservation goals and balance tradeoffs between shark bycatch and loss of tuna revenue.

Decision Context and Decision Needed: The national management agency is the decision-maker. Guidelines and recommendations from the RFMO are important considerations. A working group of diverse stakeholders is tasked with identifying preferred alternatives for the decision-maker to consider to reduce incidental catch and mortality of ETP species.

Problem Statement: What EM-enabled mitigation measures can we implement to reduce catch and fishing-associated mortality of ETP sharks, while still providing opportunities to catch marketable shark species?

STEP 2 | Objective Setting: *What do we hope to achieve?*

Fundamental Objective 1: Reduce catch and mortality of ETP species by 75% over 3 years by augmenting retention bans with additional EM-enabled mitigation measures.

Fundamental Objective 2: Reduce fishing interactions with ETP shark species by 75% over 3 years.

Fundamental Objective 3: Protect all important pupping / nursery areas for ETP shark species within 3 years.

STEP 3 | Alternatives: *What could we do?*

Potential alternatives that could meet objectives 1 and 2 were identified using the Mitigation Assessment (Appendix B) and working group knowledge. Two mitigation measures were identified as being EM-relevant, appropriate to LL gear, and having medium or high potential for shark catch Type 1 (targeted) or 2 (retained incidental catch) fisheries. A third measure (spatial-temporal closure) was identified as appropriate given the fishery and management context, despite being assessed as low potential for Type 1 and 2 fisheries in the Mitigation Assessment. The working group determined these four alternatives (or combinations of alternatives) should be considered further:

A. Retention limit for marketable shark species

B. Limit vessels or vessel-days

C. Spatial-temporal closure(s) in areas with high ETP shark catch

D. Alternative B (limit vessel days) + Alternative C (spatial-temporal closure)

STEP 4 | Consequences: *What are the predicted outcomes of different alternatives and how will they meet objectives?*

The Mitigation Assessment provided a first approximation for how well each measure would perform to meet objectives based on a variety of criteria. This information was carefully reviewed by the working group based on the local fishery context and summarized in a consequence table.

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Consequence Table: All of the information on the alternatives in this table came from the Mitigation Assessment (Appendix B), except for the information in some cells which was provided by the working group (denoted by *).

Objectives	Measurable Attribute (desired direction)	Alt. A Retention limit for market shark species	Alt. B Limit vessels or vessel days	Alt. C Spatial-temporal closure	Alt. D Alt B. Limit vessel days and Alt C. spatial-temporal closure
	Mitigation Hierarchy Tier (Avoid)	Remediate	Avoid	Avoid	Avoid
	Application (broad use)	Broad use	Broad use	Broad use	Broad use*
1. Reduce catch & mortality of ETP species	Shark catch rate (reduce)	No	Yes	Yes	Yes*
1. Reduce at-vessel mortality	Shark mortality rate (reduce)	Yes	No	No	No*
1. Reduce catch and at-vessel mortality	Strength of evidence (High)	Medium	High	Low	Medium*
2. Reduce fishing interactions w/ ETP species	Spatial overlap fishing & ETP shark catch (low)	Medium*	Medium*	Low*	Low*
3. Protect pupping/ nursery areas	Protection of pupping areas (high)	Low*	Low*	High*	High*
Score:		**14**	**18**	**17**	**18**

(Scoring: Green = 3, Yellow = 2, Red = 1)

** based on working group assessment*

At this point, the scores for the alternatives are fairly similar based on consequences.

STEP 5 | Trade-Offs: *What are the trade-offs among objectives and alternatives?*

The working group discussed tradeoffs and determined that all objectives were equally important; other important considerations they wanted to evaluate were incorporated into a summary table. Some of the considerations came from the Mitigation Assessment (Appendix B), while others fishery-specific considerations were identified by the working group (indicated by *) and reflect the managing agency's interest in a data-driven adaptive management approach to balancing conservation and fishery economics.

Other Considerations: The information on the alternatives in this table came from the Mitigation Assessment (Appendix B) and input from the working group (denoted by *).

Other Considerations	Measurable attribute (desired direction)	Alt. A Retention limit for marketed shark species	Alt. B Limit vessels or vessel days	Alt. C Spatial-temporal closure	Alt. D Alt B. Limit vessel days and Alt C. Spatial -temporal closure
Score from Step 4:		**14**	**18**	**17**	**18**
Practicality costs	(low)	Low	Low	High	Medium
Other fishery specific consideration: Conservation areas to meet 30x30 goals	Area of ocean in conservation status (yes)	No*	No*	Yes*	Yes*
Other fishery specific consideration: adaptive management	Ease of adaptive management to balance costs-benefits (high)	Low*	Medium*	High*	Medium-High*
Sum Score:		**19**	**24**	**24**	**25**

** based on working group assessment*

The working group discussed each of the alternatives, their sum score, and associated risks and uncertainties based on their expert knowledge and available scientific literature. Some highlights of their review:

A. **Retention limit for marketed shark species**—a retention limit for marketed shark species was determined to be difficult to enforce given the local market context.

B. **Limit number of vessels or vessel days**—limiting vessels or vessel days could reduce shark catch but at some economic cost to the fishery. Increased fishing effort by remaining vessels could offset benefits from this action.

C. **Spatial-temporal closure of high shark bycatch area**—this alternative would create a seasonal shark protected area in areas of high catch of ETP shark species to reduce fishing pressure (Goetz et al., 2024). Importantly, this area would need to be carefully designed to manage tradeoffs between bycatch reduction and loss of tuna catch (Watson et al., 2009; Ward-Paige, 2017). A spatial analysis conducted using existing EM data indicates that seasonally closing 20% of ETP shark bycatch hotspots could significantly reduce fishery interactions and be managed adaptively to minimize economic impacts on tuna catch. A more permanent closure of shark nursery and pupping areas would have minimal impact on export tuna catch and would benefit ETP species.

D. **Retention limit for marketed shark species (Alternative A) and Spatial -temporal closure of high shark bycatch area (Alternative C)**—while this alternative scored the best, the combined economic costs to the fleet of reducing vessel days and closing fishing grounds was deemed unacceptable.

STEP 6 | Decision: *What should we do to best achieve our objectives?*

The working group discussed the consequences and tradeoffs, potential economic impacts, and risks associated with each measure, as well as government priorities to meet ocean conservation goals. Ultimately, the working group recommended Alternative C to the decision-maker as the preferred alternative to meet all the objectives, with the caveat that spatial-temporal closures be designed to balance tradeoffs between reducing shark bycatch and economic costs to the tuna fishery. The existing enabling conditions were considered sufficient to support these actions, with an additional focus on using vessel AIS to monitor compliance with spatial closures.

STEP 7 | Act, Monitor and Learn: *Can we design interventions and monitoring to advance learning and adaptive management?*

An implementation plan should be developed to identify all the activities and timeline needed to conduct the necessary spatial analyses of existing EM data and design and implement the spatial-temporal closure areas. Monitoring of the performance of this spatial management action aimed at reducing ETP shark catch and mortality, as well as monitoring compliance with the closure areas, will be evaluated through the EM system and vessel Automatic Identification System. EM design considerations for spatial-temporal closures (from Appendix C) include: full deck coverage, continuous recording, and geo-fencing. An adaptive management plan would need to incorporate regular review of catch rates and compliance with spatial management regulations to inform needed adjustments in timing and/or location of closures to better meet objectives.

11.0 Conclusion

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The Shark Bycatch Mitigation DST can be used to identify EM-enabled, place-based, and fishery-specific shark bycatch mitigation measures that can support transparent decisions that drive more sustainable fisheries management and protect threatened shark populations. The SDM approach creates a process and provides the enabling conditions that give decision-makers and other fisheries stakeholders the ability to make decisions to achieve the desired outcomes and support learning and adaptive management. Leveraging EM for monitoring and evaluation will allow stakeholders to assess the effectiveness of their selected shark bycatch mitigation measure(s) and adaptively manage their fishery as needed to ensure objectives are being met. The Shark Bycatch Mitigation DST will support inclusive decision-making processes to address some of the most urgent challenges across global fisheries and drive fisheries management toward more sustainable practices that protect threatened species and support global ocean ecological health.

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Appendices: Resources

A. Fishery Characterization Questionnaire

Instructions: Use this questionnaire to help characterize the key features of your fishery that need to be understood to inform decisions on shark bycatch management and monitoring. Use existing information, data, and expert judgment to answer as many questions as possible. Most fisheries will not have enough information to answer all the questions; some questions may not be relevant to your fishery and do not need to be answered. Summarize existing data relevant to bycatch management in appendices.

Fishery Name: ______________________________

Geographic Region: ______________________________

SECTION 1 | Fishery and Fleet Characteristics:

A. Describe the fishing method, gear, and gear configuration. (If a multi-gear fishery, then compile characteristics separately for each gear type)

B. What are the target species and non-commercial species caught? What are the top 5 species in terms of value? What are the top 5 species in terms of volume?

C. What is the average amount of fish retained per set and per trip?

D. How many fishing trips are conducted per year? What is the duration of trips, on average? Is fishing seasonal or year-round? If seasonal, in what months does fishing typically occur?

E. Are different species/species-groups targeted at different times of the year?

F. Is this a domestic or international fleet? How many vessels are in the fleet?

G. What is the total catch reported by the fleet annually (ideally by species or with some taxonomic resolution)?

H. Where does fishing occur? Do the fishing grounds change over the course of the year? Do vessels fish outside the EEZ?

I. What is the average vessel size (length, tonnage)? Do they have refrigerated holds?

J. How many crew members per vessel? What is the nature of their employment contract and compensation?

SECTION 2 | Shark Catch Characterization:

A. Which of the following best describes shark fishing practices in this fishery? (More than one type might apply.)

- Type 1: Sharks targeted.
- Type 2: Sharks retained, incidental catch.
- Type 3: Shark fins retained, remaining carcass discarded.
- Type 4: Sharks not retained.

B. Are there any current shark catch regulations in the fishery? If so, what are they and are there any associated mitigation measures?

C. If not addressed above in Section 1 and information is available, what species of sharks/rays are caught? What is the fate of these species—are they targeted, retained incidentally, finned, or discarded?

D. What is the average total catch of sharks and rays (ideally by species or with some taxonomic resolution) per trip and annually?

E. For shark species that are not retained, what is known about the causes of shark mortality (e.g. pre-catch losses, dead discards, post-release mortality, unknown)?

F. What endangered, threatened, or protected (ETP) shark/ray species are susceptible to capture in this fishery? Are there some areas or seasons when ETP shark/ray catch is highest?

G. Are there other vulnerable or ETP species (e.g. sea turtles, seabirds, cetaceans) caught in this fishery?

SECTION 3 | Fishery Management/Human Context:

A. Who is the fishery management agency? What kind of management framework is in place? (e.g. quota system, gear restrictions, catch limits, area closures, species bans, etc.) Is this fishery part of a FIP and, if so, what are the management requirements listed under that FIP?

B. What existing policies or regulations focus on catch of sharks? What bycatch mitigation measures are currently employed in this fishery?

C. How is compliance with regulations monitored and enforced? Are the regulations being followed? Do they have the intended impact on bycatch?

D. Is this fishery part of a Regional Fishery Management Organization (RFMO)? Does the RMFO have any binding conservation or management measures related to shark/ray bycatch?

E. What are the existing market drivers or other incentives or disincentives related to shark/ray catch (e.g. high market demand or market values, Marine Stewardship Council Fishery Standard, cultural values, etc.)?

SECTION 4 | Existing Monitoring Programs and Data:

A. Describe the current monitoring programs in place. Is there a port sampling program? Are there logbook requirements? If so, what are they?

B. Are independent data currently collected through VMS, EM and/or Observer Programs?

If there is an observer program: Yes/No. If Yes,

- What is the observer coverage (percent) for the fleet?
- What types of data are collected by observers?
- What proportion of sets in a trip are typically observed?
- Who owns and has access to observer data?
- What is the total cost of the observer program?

Is there an EM program: Yes/No. If Yes,

- What proportion of vessels in the fleet have EM? Are these vessels representative of the fleet?
- How is the EM system setup (e.g., number of cameras, camera placement, sensor-based or continuous recording)? Does this setup vary by vessel or is it standardized across the fleet?

- What proportion of EM data are reviewed? What types of data are recorded by the reviewers? How long does it take to get reviewed data?
- Who owns the EM data? Who has access to the EM data?
- What is the initial investment cost for the EM program (e.g., equipment, installation, training) and who pays those costs? What is the annual cost of maintaining the program (e.g., data review, storage, management time, etc.) and who pays those costs?

C. Are there other data sources related to catch and bycatch for this fishery?

D. Summarize any relevant monitoring datasets in the Appendix.

SECTION 5 | Sources of Information:

What sources of information were used for this characterization?

Experts: ____________________

Datasets: ____________________

Reports: ____________________

Other: ____________________

APPENDICES: *[Add any data summaries, maps, or reports here]*

B. Assessment of Shark Bycatch Mitigation Measures ('Mitigation Assessment')

The bycatch mitigation methods included are generally commercially available and with at least some industry uptake; however, some methods that currently have limited or no industry uptake, including those that are in the concept or initial research and development (R&D) stage, and that are not commercially available, as noted in the "Stage of Development" column. Each mitigation method was categorized for the following fields, based on the judgement of the author, (Gilman, Unpublished Technical Report, 2023):

- **Gear:** relevant gear of pelagic longline, combined trawl (pelagic, midwater, bottom) and combined gillnet (drift and anchored)
- **Mitigation hierarchy tier:** bycatch mitigation methods that avoid bycatch are considered before those that minimize catch risk. These are then followed by remediation interventions that reduce fishing mortality and sublethal impacts. Finally, offsets of residual impacts that were not possible to avoid, minimize and remediate are considered as a last resort.
- **Stage of development:** R&D of prototypes, preliminary trials and experiments, a few individual fisheries, broad use.
- Does the method **Reduce shark catch?** (Y = yes or N = no, with considerations listed)
- Does the method **Reduce shark fishing mortality rate?** (Y = yes or N = no, with considerations listed)
- **Strength of evidence** that the method effectively mitigates shark catch rate or fishing mortality rate: high, medium, low
- **Potential for conflict for other at-risk species**: high, medium, low.
- **Deviation from fishing method/gear designs**: high, medium, low.
- **Economic cost**: high, medium, low.
- **Practicality cost**: high, medium, low.
- **Safety cost** for crew: high, medium, low.
- If efficacy **Relies on crew behavior**: (Y = yes or N = no)
- Does the method **Require strong management**, i.e., a national fisheries management framework with sufficient monitoring, control, surveillance and enforcement: high, medium or low.
- **Fishery Type Potential**: the potential (high, medium, low) for application across the 4 fishery typologies the method might be suitable where 1 = sharks are the main target; 2= retain carcasses of incidentally caught sharks; 3 = retain fins of incidentally caught sharks; 4 = sharks are not retained.
- **EM Relevance**: methods that can be effectively monitored with electronic monitoring (EM); yes or no.

TABLE B1. Methods identified to mitigate the catch rate and fishing mortality of shark species that are susceptible to capture in pelagic longline, combined trawl (pelagic, midwater, bottom) and combined gillnet (drift and anchored) fisheries.

Intervention Category	Method	Gear	Mitigation hierarchy tier	Stage of development	Reduce shark catch rate?	Reduce shark fishing mortality rate?	Strength of evidence	Potential for conflict for other at-risk species	Deviation from fishing method/ gear design	Economic cost	Practicality cost	Safety cost	Relies on crew behavior	Requires strong management	Fishery Type Potential	Compliance monitoring approach	EM Relevance
Output Control	Ban shark finning (retain fins and discard remaining carcass)	longline, gillnet, trawl	minimize, remediate	broad use	N	Y (epi, meso, benthic)	low	low	low	high	low	low	Y	med	High 1; 2; 3	at-sea ind. monitoring, port sampling	Y
	Retention limit (individual or fleet-based, for marketable species)	longline, gillnet, trawl	remediate	broad use	N	Y (epi, meso, benthic)	med	low	low	high	low	low	N	low	High 1; 2; 3; 4	at-sea ind. monitoring, port sampling	Y
	Retention ban, international trade ban	longline, gillnet, trawl	remediate	broad use	N	Y (epi, meso, benthic)	med	low	low	high	low	low	N	low	High 4	at-sea ind. monitoring, port sampling	Y
	Bycatch thresholds	longline, gillnet, trawl	avoid	a few fisheries	Y (epi, meso, benthic)	N	med	low	low	high	low	low	N	high	Low	at-sea ind. monitoring	Y
Input Control	Limit duration of fishing operation (soak in passive fishing gear, tow in active fishing gear)	longline, gillnet, trawl	minimize, remediate	broad use	Y (epi, meso, benthic)	Y (epi, meso, benthic)	low	low	med	med	med	low	Y	high	High 1; 2; 3; 4	at-sea ind. monitoring, VMS	Y
	Limit number of vessels, vessel size, amount of gear, fishing days, number of fishing operations	longline, gillnet, trawl	avoid	broad use	Y (epi, meso, benthic)	N	high	low	low	high	low	low	N	med	High 1; 2; 3; 4	VMS	N
Handling	Handling and release practices	longline, gillnet, trawl	remediate	broad use	N	Y (epi, meso, benthic)	med	low	low	low	med	low	Y	high	Med 1; 2; 3; 4	at-sea ind. monitoring	Y
ALDFG	ALDFG: Mitigate risk of producing and adverse effects of derelict gear	longline, gillnet, trawl	remediate	broad use	N	Y (epi, meso, benthic)	low	low	med	med	med	low	N	high	High 1; 2; 3; 4	at-sea ind. monitoring, dockside inspections	Y

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Intervention Category	Method	Gear	Mitigation hierarchy tier	Stage of development	Reduce shark catch rate?	Reduce shark fishing mortality rate?	Strength of evidence	Potential for conflict for other at-risk species	Deviation from fishing method/ gear design	Economic cost	Practicality cost	Safety cost	Relies on crew behavior	Requires strong management	Fishery Type Potential	Compliance monitoring approach	EM Relevance
Gear Tech (Methods or Gear)	Lazy line: ban shark lazy line (attaching sharks to a line off the stern where sharks are temporarily attached during the gear haulback)	longline	remediate	unknown	N	Y (epi, meso)	low	low	med	low	med	med	Y	high	High 1; 2; 3; 4	at-sea ind. monitoring	Y
	Branchline length: relatively long branchlines (to increase rate of at-vessel survival of obligate ram-ventilating sharks)	longline	remediate	unknown	N	Y (meso)	low	med	med	med	med	low	Y	low	High 1; 2; 3; 4	at-sea ind. monitoring, dockside inspections	N
	Shark line: ban shark lines (branchlines that fish near the surface, through attachment to floats or floatlines)	longline	minimize	broad use	Y (epi, meso)	N (increases at-vessel mortality)	high	med	med	med	low	low	Y	high	High 4	at-sea ind. monitoring	Y
	Leader type: Monofilament leaders only (ban wire and multifilament leaders)	longline	minimize, remediate	broad use	Y (epi, meso)	Y (epi, meso)	high	low	high	high	low	high	N	low	High 4	at-sea ind. monitoring, dockside inspections	Y
	Repellants (e.g., rare earth electropostive metals, chemical/olfactory, electrical, magnetic, acoustic)	longline, gillnet, trawl	minimize	R&D	Y (epi, meso)	N	low	low	high	high	high	low	Y	high	Low	at-sea ind. monitoring	N
	Excluder (sorting) and guiding grids: Grid/grate attached within the neck of a trawl, before the codend, that guides unwanted larger species including some sharks to an escape opening.*	trawl	minimize	broad use	Y (epi, meso, benthic)	N	high	low	med	med	low	low	N	med	Med 4	at-sea ind. monitoring, dockside inspections	N
	Ban tickler chains: do not use a tickler (chain attached in front of the groundgear footrope and rock-hoppers)	trawl	minimize	R&D	Y (benthic)	N	med	low	med	high	low	low	Y	med	Low	at-sea ind. monitoring, dockside inspections	Y
	Manage mesh size: Manage mesh size to control the gilling size selectivity of gillnets.**	gillnet	minimize	broad use	Y (epi, meso, benthic)	N	high	high	high	high	low	low	N	med	Med 4	at-sea ind. monitoring, dockside inspections	N

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Intervention Category	Method	Gear	Mitigation hierarchy tier	Stage of development	Reduce shark catch rate?	Reduce shark fishing mortality rate?	Strength of evidence	Potential for conflict for other at-risk species	Deviation from fishing method/ gear design	Economic cost	Practicality cost	Safety cost	Relies on crew behavior	Requires strong management	Fishery Type Potential	Compliance monitoring approach	EM Relevance
Gear Tech (Methods or Gear) (*cont.*)	Stiffer netting: Can reduce entanglement risk for large organisms. May also reduce the time required for crew to disentangle and release catch.***	gillnet	minimize, remediate	unknown	Y (epi, meso, benthic)	Y (epi, meso, benthic)	low (for shark catch rate response)	low	high	high	medium	low	N	med	Low	at-sea ind. monitoring, dockside inspections	N
	Less durable netting: Use of less durable materials can produce a breaking strength that allows large organisms to break free of the gear and escape.	gillnet	minimize	unknown	Y (epi, meso, benthic)	N	low	low	high	high	low	low	N	high	Low	at-sea ind. monitoring, dockside inspections	N
Spatio-Temporal Mgmt	Static and dynamic spatial and temporal restrictions	longline, gillnet, trawl	avoid	broad use	Y (epi, meso, benthic)	N	low	high	high	high	low	low	N	med	Med 4	at-sea ind. monitoring, VMS	Y
	Real-time fleet communication	longline, gillnet, trawl	minimize	a few fisheries	Y (epi, meso, benthic)	N	med	high	high	high	low	low	Y	high	Med 4	at-sea ind. monitoring	N
	Real-time move-on rules	longline, gillnet, trawl	minimize	broad use	Y (epi, meso, benthic)	N	low	high	high	high	low	low	N	high	Low	at-sea ind. monitoring	N
Methods used to mitigate other at-risk species that may also benefit sharks	Circle shaped instead of J-shaped hook of the same size	longline	remediate	broad use	N (increases catch rate of some epipelagic sharks)	Y	high	high	med	medium	low	low	N	low	High 1; 2; 3; 4	at-sea ind. monitoring, dockside inspections	Y
	J-shaped instead of circle shaped hook of the same size	longline	minimize	broad use	Y	N (increases at-vessel mortality rate of some epi-pelagic sharks)	high	high	med	medium	low	low	N	low	Med 4	at-sea ind. monitoring, dockside inspections	Y
	Forage fish bait instead of squid bait	longline	minimize	a few fisheries	Y (epi, meso, benthic)	N (increases at-vessel mortality)	med	low	med	high	low	low	N	low	Med 4	at-sea ind. monitoring, dockside inspections	Y
	Ban lightsticks	longline	minimize	a few fisheries	Y (meso, maybe others)	N	med	low	high	high	low	low	N	low	Med 4	at-sea ind. monitoring, dockside inspections	Y

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Intervention Category	Method	Gear	Mitigation hierarchy tier	Stage of development	Reduce shark catch rate?	Reduce shark fishing mortality rate?	Strength of evidence	Potential for conflict for other at-risk species	Deviation from fishing method/ gear design	Economic cost	Practicality cost	Safety cost	Relies on crew behavior	Requires strong management	Fishery Type Potential	Compliance monitoring approach	EM Relevance
Methods used to mitigate other at-risk species that may also benefit sharks (cont.)	Deeper (hooks soak >100 m) daytime fishing as compared to shallower nighttime fishing	longline	minimize	a few fisheries	Y (epi)	N (increases at-vessel mortality)	high	high	high	high	med	low	Y	high	Med 4	at-sea ind. monitoring	Y
	Wider hook	longline	minimize	a few fisheries	Y (epi, meso, benthic)	N	low	high	high	high	low	low	N	low	Med 4	at-sea ind. monitoring, dockside inspections	N
	Depth of shallowest hook >100 m	longline	minimize	a few fisheries	Y (epi)	N (increases at-vessel mortality)	high	high	high	high	med	low	Y	high	Med 4	at-sea ind. monitoring	N
	Artificial bait	longline	minimize	R&D	Y (epi, meso)	N	low	low	high	high	unknown	low	N	high	Low	at-sea ind. monitoring, dockside inspections	Y
	Weak hook	longline	minimize, remediate	a few fisheries	Y (epi, meso, benthic)	Y (epi, meso, benthic)	low	low	high	med	low	low	N	med	Low	at-sea ind. monitoring, dockside inspections	N
	Mesh shape: square meshes in the neck of the trawl.	trawl	minimize, remediate	broad use	Y (epi, meso, benthic)	Y (epi, meso, benthic)	low	med	med	med	low	low	N	med	Med 1; 2; 3; 4	at-sea ind. monitoring, dockside inspections	N
	Raised footrope: the "mouth" is raised so that it does not drag across the seabed	trawl	minimize	broad use	Y (benthic)	N	low	low	low	med	low	low	Y	high	Med 1; 2; 3; 4	at-sea ind. monitoring	N
	Guiding grid and bycatch codend: a guiding grid directs unwanted large bycatch species into a second 'bycatch codend" for species that may not exit through an escape panel.	trawl	minimize, remediate	R&D	Y (epi, meso, benthic)	Y (epi, meso, benthic)	low	low	high	med	high	low	N	high	Med 4	at-sea ind. monitoring	N

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Intervention Category	Method	Gear	Mitigation hierarchy tier	Stage of development	Reduce shark catch rate?	Reduce shark fishing mortality rate?	Strength of evidence	Potential for conflict for other at-risk species	Deviation from fishing method/ gear design	Economic cost	Practicality cost	Safety cost	Relies on crew behavior	Requires strong management	Fishery Type Potential	Compliance monitoring approach	EM Relevance
Methods used to mitigate other at-risk species that may also benefit sharks (cont.)	Illumination: attaching lights to gillnets reduces capture risk of marine turtles, elasmobranchs and seabirds	gillnet	minimize	unknown	Y (epi, meso, benthic)	N	med	low	med	med	med****	low	Y	high	High 4	at-sea ind. monitoring	Y
	Tie-downs: Increase the length or eliminate tie-downs in anchored gillnets, reducing entanglement risk of large organisms by reducing or eliminating the bag of slack webbing	gillnet	minimize	a few fisheries	Y (epi, meso, benthic)	N	med	low	high	high	low	low	Y	high	Med 1; 2; 3; 4	at-sea ind. monitoring	Y
	Deeper fishing: setting gillnets deeper and/or using lower profile panels can reduce vertical depth overlap with epipelagic species	gillnet	minimize	a few fisheries	Y (epi)	N	high	high	high	high	high	low	Y	high	Med 1; 2; 3; 4	at-sea ind. monitoring	N
Offsets	Offsets	longline, gillnet, trawl	offset	prelimi-nary trials	N	N	low	low	low	med	low	low	N	high	Low	at-sea ind. monitoring	N

C. Electronic Monitoring Considerations

Using electronic monitoring (EM) for shark bycatch mitigation requires the system to be designed and implemented appropriately for each mitigation measure. Of the 37 mitigation measures, 22 were determined to be EM-enabled (i.e., EM can be an effective tool for monitoring and compliance; Table C2). For each EM-enabled mitigation measure, we evaluate what considerations for EM system design, implementation, and review are required to ensure effective monitoring and compliance with the mitigation measure. The 12 EM considerations are defined in Table C1.

TABLE C1. Electronic monitoring considerations and definitions.

Consideration	Definition
Full deck coverage	Requires multiple cameras so that the entire deck is visible
Off-deck coverage	Requires cameras that can see off the side of the vessel (e.g., to view gear in the water, handling over the side, etc.)
Continuous recording	Requires continuous recording not sensor-based start/stop recording
Geofencing	Requires sensors to be tied to geographic location
Crew cooperation	Requires crew behavior changes (e.g., holding gear up to a camera); training and/or feedback with EM review
Operational procedures	Requires new operational procedures or changes to procedures (e.g., using long handle line cutters; hauling in site of cameras)
Gear configuration	Requires the ability to view gear in the water (e.g., count hooks between floats); might work for some gear configurations but not for others (e.g., single v. multiple mainlines), could benefit from gear alterations (e.g., using a different color rope)
Gear sensors	Requires hydraulic gear sensors
Full review	Requires full or near full review of EM footage
Frequent review	Requires timely and more frequent review of EM (e.g., every trip instead of randomly sampled trips)
New data parameters	Requires EM analysts to record data on a new parameter
Regulatory variation	Requires consideration of regulatory setting in different countries/fisheries; might work well for some types of regulations but not as well for others (e.g., applies to all sharks vs. species-specific)

TABLE C2: EM-enabled shark bycatch mitigation measures by gear and fishery type potential and considerations required for EM to be effective for monitoring and enforcement of each mitigation measure.

Category	Method	Gear	Fishery Type Potential	EM Relevance	EM Considerations
Output Control	Ban shark finning (retain fins and discard remaining carcass)	longline, gillnet, trawl	High 1; 2; 3	Y	full deck coverage; continuous recording; full review; frequent review; regulatory variation
	Retention limit (individual or fleet-based, for marketable species)	longline, gillnet, trawl	High 1; 2; 3; 4	Y	full deck coverage; off-deck coverage; continuous recording; full review; frequent review
	Retention ban, international trade ban	longline, gillnet, trawl	High 4	Y	full deck coverage; off-deck coverage; continuous recording; full review; frequent review
	Bycatch thresholds	longline, gillnet, trawl	Low	Y	full deck coverage; off-deck coverage; continuous recording; full review; frequent review
Input control	Limit duration of fishing operation (soak in passive fishing gear, tow in active fishing gear)	longline, gillnet, trawl	High 1; 2; 3; 4	Y	continuous recording; gear sensors
Handling	Handling and release practices	longline, gillnet, trawl	Med 1; 2; 3; 4	Y	full deck coverage; off-deck coverage; crew cooperation; operational procedures; new data parameters
ALDFG	ALDFG: Mitigate risk of producing and adverse effects of derelict gear	longline, gillnet, trawl	High 1; 2; 3; 4	Y	full deck coverage; off-deck coverage; continuous recording; gear sensors; gear configuration; full review; regulatory variation
Gear technology (changes to fishing methods or gear)	Lazy line: ban shark lazy line (attaching sharks to a line off the stern where sharks are temporarily attached during the gear haulback)	longline	High 1; 2; 3; 4	Y	full deck coverage; off-deck coverage; gear configuration; new data parameters
	Shark line: ban shark lines (branchlines that fish near the surface, through attachment to floats or floatlines)	longline	High 4	Y	full deck coverage; crew cooperation; gear configuration; new data parameters
	Leader type: Monofilament leaders only (ban wire and multifilament leaders)	longline	High 4	Y	full deck coverage; crew cooperation; gear configuration; new data parameters
	Ban tickler chains: do not use a tickler (chain attached in front of the ground gear footrope and rock-hoppers)	trawl	Low	Y	full deck coverage; crew cooperation; new data parameters
Spatio-temporal management	Static and dynamic spatial and temporal restrictions	longline, gillnet, trawl	Med 4	Y	full deck coverage; continuous recording; geofencing
Methods used to mitigate other at-risk species that may also benefit sharks	Circle shaped instead of J-shaped hook of the same size	longline	High 1; 2; 3; 4	Y	full deck coverage; crew cooperation; new data parameters
	J-shaped instead of circle shaped hook of the same size	longline	Med 4	Y	full deck coverage; crew cooperation; new data parameters
	Forage fish bait instead of squid bait	longline	Med 4	Y	full deck coverage; crew cooperation; new data parameters
	Ban lightsticks	longline	Med 4	Y	full deck coverage; new data parameters
	Deeper (hooks soak >100 m) daytime fishing as compared to shallower nighttime fishing	longline	Med 4	Y	full deck coverage; off-deck coverage; crew cooperation; gear configuration
	Artificial bait	longline	Low	Y	full deck coverage; crew cooperation; new data parameters
	Illumination: attaching lights to gillnets reduces capture risk of marine turtles, elasmobranchs and seabirds	gillnet	High 4	Y	full deck coverage; crew cooperation; new data parameters
	Tie-downs: Increase the length or eliminate tie-downs in anchored gillnets, reducing entanglement risk of large organisms by reducing or eliminating the bag of slack webbing	gillnet	Med 1; 2; 3; 4	Y	full deck coverage; crew cooperation; new data parameters

D. Worksheet and templates for using the Shark Bycatch Mitigation DST

Overview: The Shark Bycatch Mitigation DST is based on a 7-step structured decision-making approach intended to guide decision-makers and other stakeholders through a process to clearly identify their shark bycatch problem, management objectives, and potential management actions that can be taken to meet their objectives. This worksheet provides prompts for each step, as well as templates where the results of each step can be documented. Some pre-work to characterize your fishery and the shark bycatch issues is needed to inform this decision-making process (see Appendix A).

STEP 1 | Problem Formulation: *What is the problem we are trying to solve?*

What is the shark bycatch problem or concern in your fishery? Make sure that it is a solvable problem and represents the values of the stakeholders involved. Problems should be defined as decisions and carefully framed to guide the next steps in the process. Use information from the completed pre-work to characterize the fishery (see Appendix A) and the concerns of stakeholders to inform your problem statement.

Step 1. Problem Formulation
Describe the shark bycatch problem, challenge, or opportunity in your fishery that reflects the shared understanding and values and concerns of stakeholders, the decision context, and the type of decision needed. Create a problem statement that proposes an action that you predict will lead to outcomes that should fulfill objectives. **Background on fishery:** **Values and concerns:** **Decision context and type of decision needed:** **Problem statement:**

STEP 2 | Setting Clear Objectives: *What do we hope to achieve?*

Identify clear objectives that articulate what you hope to achieve. Objectives should be specific, measurable, achievable, relevant and time-bound (i.e. SMART). Each objective should have a measurable attribute that can be used to compare across alternatives to predict how well they might meet that objective. Measurable attributes should include a unit of measure and a preferred direction (e.g., decrease or increase; maximize or minimize). Begin to identify potential performance metrics and monitoring considerations (from Appendix C) that will need to be refined in Step 7.

Step 2. Setting Clear Objectives

Identify SMART objectives, measurable attributes (with units and preferred direction), and performance metrics (with monitoring considerations from Appendix C).

SMART Objectives	Measurable attribute (units)	Preferred direction	Potential performance metric (and monitoring considerations)
1.			
2.			
3.			
Etc.			

STEP 3 | Identifying Alternatives: *What could we do?*

Identify the subset of shark bycatch mitigation alternatives that could meet the objectives and address the problem that has been identified in the prior steps. Use the information in the Mitigation Assessment (Appendix B) to identify alternatives that are appropriate to the gear used in your fishery, have the potential to achieve objectives given the shark catch typology, are EM-relevant, and are appropriate to your fishery context. Use this information to identify which alternatives should be further evaluated.

Step 3. Identifying Alternatives

Identify shark bycatch mitigation alternatives that could achieve your objectives and that warrant further evaluation:

Mitigation Measure	Gear-specific	Shark typology potential	EM-relevant?	Location and fishery appropriate?
1.				
2.				
3.				
4.				
Etc.				

STEP 4 | Predicting Consequences: *What are the predicted outcomes of different alternatives and how will they meet objectives?*

Use criteria from the Mitigation Assessment (**Appendix B**), expert judgment, or models to predict, to the best extent possible, how well each alternative (or combinations of alternatives) will perform to meet objectives. Create a Consequence Table that links your alternatives directly to your objectives. Include criteria such as the mitigation hierarchy tier and application (state of development) of the mitigation measure, and any other criteria that *link alternatives directly to objectives*. Incorporate uncertainty into your predictions. Use a common metric across an objective to compare alternatives. A stoplight (red/yellow/green) system or simple scoring system can be used to compare across alternatives.

Step 4. Predicting Consequences

Create a Consequence Table to summarize predictions for how well each alternative (or combinations of alternatives) will achieve objectives. Use a simple scoring system to compare alternatives (e.g. red=1, yellow = 2, green =3).

Objectives	Measurable Attribute (units, desired direction)	Alternative 1	Alternative 2
Mitigation Hierarchy	Tier (avoid)		
Application	Stage of development (broad use)		
Obj. 1			
Obj. 2			
Obj. 3			
Etc.			
Sum Score			

STEP 5 | Evaluating Tradeoffs: *What are the tradeoffs among objectives and alternatives?*

Evaluate tradeoffs among alternatives, as well as risks, sources of uncertainty, feasibility, and other considerations relevant to the decision. If some objectives are more important than others, then tradeoffs among objectives may be needed. Are the risks and uncertainties of each alternative acceptable to decision-makers? Are there logistical, financial, or regulatory constraints that affect feasibility of each alternative? Use criteria from the Mitigation Assessment (Appendix B) or from the working group that address these other considerations. Add to the stoplight or scoring system used in Step 4 to help identify preferred alternatives; the scores of more important objectives or considerations can be weighted. Then briefly summarize how well each alternative would be expected to meet objectives, as well as any concerns or risks that should inform the decision.

Step 5. Evaluating Tradeoffs

Add rows to the Consequence Table to cover other considerations and assess how each alternative would be expected to perform. Identify any objectives or criteria that are more important than others and consider weighting their scores higher.

Other Considerations	Measurable attribute (units, desired direction)	Alternative 1	Alternative 2	Alternative 3
Score from Step 4				
Sum Score				

Step 5. Summarize the benefits, risks, uncertainties, other considerations, and tradeoffs among alternatives.

Alt 1:

Alt 2:

Alt 3:

Alt 1 + 3:

STEP 6 | Making Decisions: *What should we do to best achieve our objectives?*

Select the 'best' mitigation alternative (or combination of alternatives), given your current understanding of the consequences, tradeoffs, risks and uncertainty of each alternative and how appropriate that alternative is for the local fishery and shark bycatch context. Consider the risks associated with each alternative and the risk tolerance of the decision-maker. Address uncertainty and identify if more information is required before a decision is made. Use scores from Steps 4 and 5, rank choice voting, or other tools to elucidate preferences and identify preferred alternatives. Document the decision.

Step 6. Document the decision
1. What is the preferred mitigation alternative and why was it selected?
2. Are there significant risks or sources of uncertainty that the decision-maker should be aware of?
3. Are there important enabling conditions that need to be in place for this decision to be effective?

STEP 7 | Act, Monitor, and Learn: *Can we design interventions and monitoring to advance learning and adaptive management?*

Outline an implementation plan that clearly articulates the overarching goal, objectives, action(s) selected, activities, responsible parties, and timeline to implement the selected mitigation measures.

Develop a plan to monitor the performance of the selected alternatives at meeting objectives, as well as monitoring compliance with mitigation measures. Performance metrics identified in Step 2 should be refined, as needed. Identify the role of EM and other monitoring approaches to assess performance and compliance. EM design considerations for the selected mitigation measures can be found in Appendix C.

Briefly outline an adaptive management plan to review the effectiveness of mitigation measures and compliance with mitigation measures, and how adjustments will be made to meet objectives.

Step 7. Act, Monitor, and Learn
1. Implementation Plan—briefly describe the core elements of an Implementation Plan.
2. Monitoring Plan—briefly describe the core elements of a Monitoring Plan.
3. Adaptive Management Plan—briefly describe the plan to test, review, and iterate on the decision being implemented to ensure successful outcomes.

E. RFMO Shark Conservation Management & Bycatch Resources

Many RFMOs have existing conservation requirements and these should always mark the minimum of what is implemented. Outcomes of the DST should be supplemental to RFMO minimum requirements. For more information on what tuna RFMOs are relevant to your fishery, please follow these links:

Map of the RFMO Convention Areas (WCPFC, IATTC, IOTC, ICCAT, CCBST)

Links to shark conservation and management measures

WCPFC—Home | WCPFC

- Conservation and Management Measures, and Resolutions | Monitoring and Evaluation (CTRL-F "shark" to search for shark-specific information)
- As of July 2025, the most up to date shark measure is CMM 2024-05, link: CMM 2024-05—Conservation and Management Measure for Sharks | Monitoring and Evaluation

  Note: If a resolution is no longer active, it will be clearly indicated on the right side of the measure.

IATTC—Home | IATTC

- Resolutions | IATTC (CTRL-F "shark" to search for shark-specific information)
- As of July 2025, the most up to date shark measure is C-24-05, link: Sharks

  Note: If a resolution is no longer active, it will be clearly indicated on the right side of the measure.

IOTC—IOTC | Indian Ocean Tuna Commission / Commission des Thons de l'Océan Indien

- Conservation and Management Measures (CMMs) | IOTC
- CTRL-F "shark" in the compendium of active management measures: IOTC_-_Compendium_of_ACTIVE_CMMs_05_December_2024.pdf

ICCAT—ICCAT·CICTA·CICAA

- Click on compendium of management measures—ICCAT·CICTA·CICAA (CTRL-F "shark" to search for shark-specific information)

  Note: ICCAT has several shark conservation and management measures, they will be distinguished (active vs. non-active)