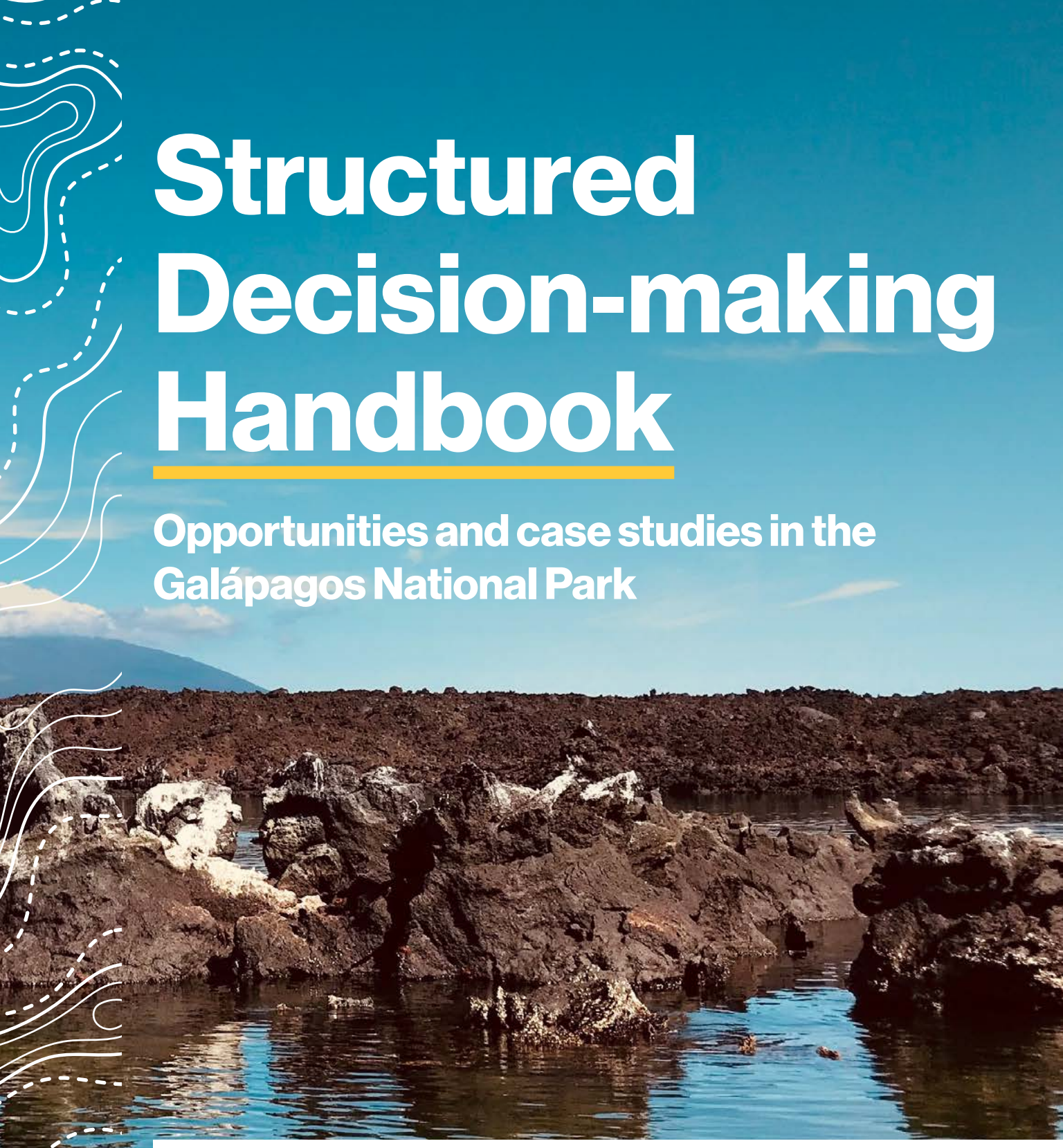
Structured Decision-making Handbook

Opportunities and case studies in the Galápagos National Park



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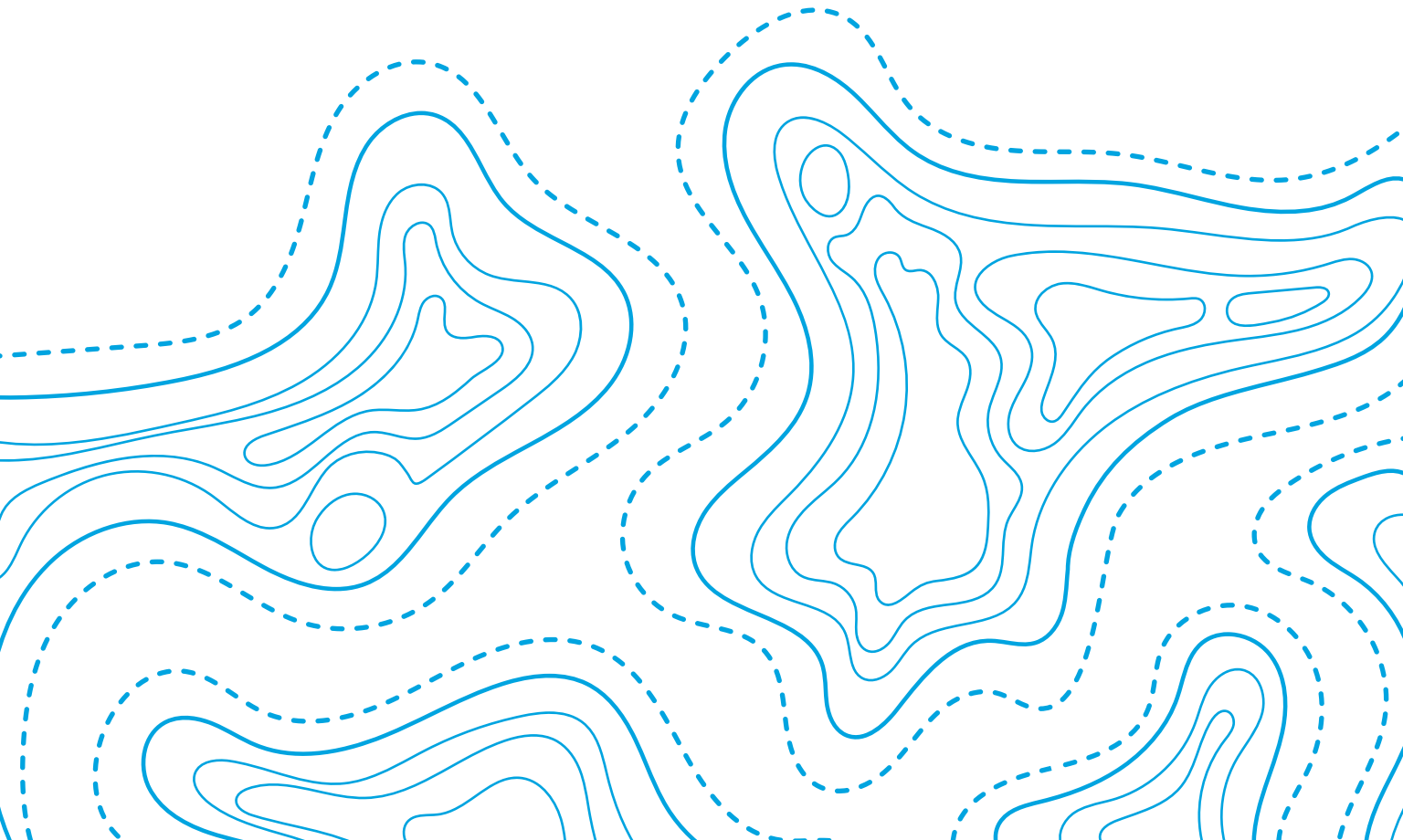

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Lenfest team conducting underwater research in the Galápagos Marine Reserve

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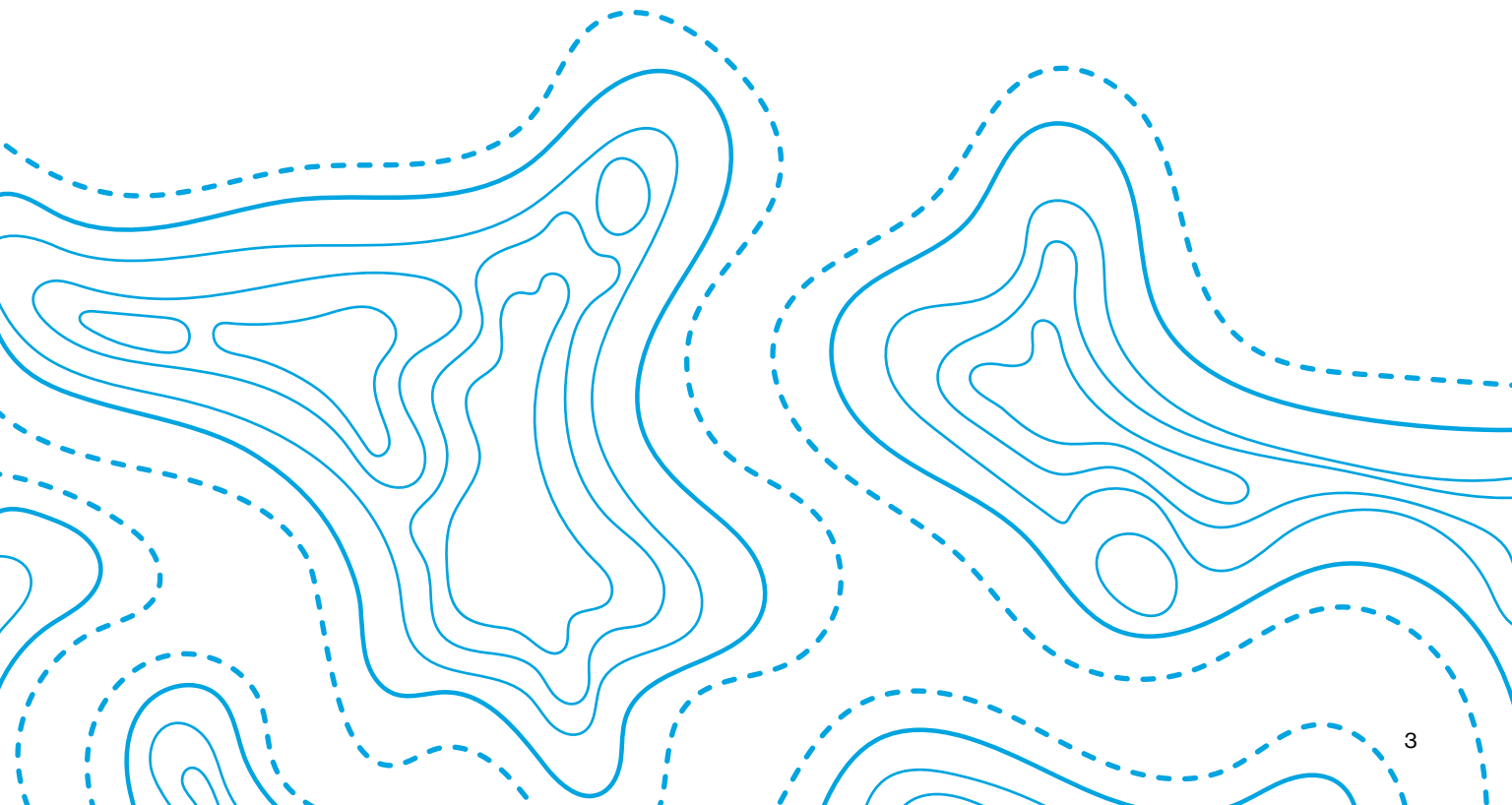
Leah Gerber

Why This Handbook?

The Galápagos Islands support unique and rich levels of biodiversity, which the Galápagos Marine Reserve (GMR) protects. The GMR is one of the largest marine reserves in the world and is a UNESCO World Heritage Site. Yet the GMR faces conflicting social, political, and economic objectives that challenge how park managers manage the GMR. Limited financial resources of park managers constrain conservation options; in addition, local communities have disengaged from conservation planning efforts due to a lack of transparency in the decision-making process. With an insufficient budget, park managers are not able to formally assess how interventions affect and achieve stated objectives. Because of these issues, stakeholders have become skeptical about the management of the reserve.

With this handbook, we intend to assist the Galápagos National Park Directorate (GNPD) to refine management objectives and apply data analyses to inform adaptive management and decision-making within the GMR. The handbook outlines the application of structured decision-making (SDM) as a rigorous foundation for evaluating decisions in a transparent manner. SDM gives park managers a practical, hands-on method to effectively target resources, then pursue objectives, prioritize interventions, and implement decisions, all while building trust among stakeholders.

This handbook guides users through employing SDM to support environmental management decisions in the GMR. The handbook is divided into four parts. Section One introduces the SDM process and gives an overview of each step. Section Two explains how the SDM process can support GMR management. Section Three explores a case study of sea cucumber fisheries that illustrates how to apply this process in the Galápagos Marine Reserve. Section Four includes an introductory guide to a data management tool – an interactive Microsoft Excel workbook – that we developed to help managers collect and query management strategy cost and benefit data tailored to implement the SDM steps.



Green sea turtle in the Galápagos islands

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Joshua Vela

Section 1: What Is Structured Decision-Making (SDM)?

Conservation managers often choose between several alternatives (actions or sets of actions) when pursuing a desired objective[2]. Structured decision-making (SDM) is a process that enables institutional knowledge, scientific research, and stakeholder values to be considered while evaluating trade-offs between management alternatives[2]. SDM provides a step-by-step framework for building a robust and accountable foundation for decision-making. Thus, SDM enables transparency, improved communication, and direct connection between management decisions and objectives[3]. The context of every decision is different, so it's important to know whether an SDM approach is right for the given context. By reviewing the questions in Box 1, we can see that not all management problems involve a decision that requires an SDM approach, such as situations where there are unlimited resources and clear objectives.

SDM allows stakeholders and decision-makers to build a common path toward finding solutions to management problems. SDM can build consensus for a responsible and defensible approach to making an environmental decision, and its formality and repeatable methods increase the likelihood of successful conservation strategies[2]. By strategies, we mean a set of activities that work together to achieve specific objectives by targeting key intervention points[4].

Box 1: Identifying whether SDM is the right tool

Not all management problems involve a decision that requires an SDM approach. Here are key questions to determine if the SDM approach is appropriate in a decision-making process:

1. What is the problem?
2. Does a decision need to be made?
3. Does this decision involve choosing between multiple alternatives?
4. Does this decision involve several stakeholders or users?

SDM is a six-step process that walks decision-makers through a systematic comparison of how possible alternatives perform in relation to their objectives (SDM does not provide a solution to a problem on its own) (see Figure 1). The steps are (1) define the problem, (2) set the objectives, (3) consider alternatives, (4) estimate consequences, (5) determine trade-offs, and (6) implement and monitor decisions.

Figure 1. Steps in the SDM Framework

1	**Define the problem**	What problem requires a solution?
2	**Set the objective**	What do you want to achieve?
3	**Alternatives**	What can you do?
4	**Consequences**	How do the things you can do help you get what you want?
5	**Trade-offs**	Choose from the things you can do to get what you want.
6	**Decision**	Do and learn.

Step 1: Define the Problem

Defining the problem is fundamental to the SDM process, setting the foundation for the entire decision-making process. It involves clearly defining and articulating the problem at hand, as well as providing a comprehensive understanding of the nature, scope, and complexity of the problem[1].

Three main questions need to be addressed in this step[5]:

1. What is the desired outcome of the decision?
2. What does the decision-maker need to support the decision?
3. Who is/are the decision-maker/s?

Defining the problem correctly helps to establish a clear foundation for objective setting (step 2), considering alternatives (step 3), and the other subsequent steps of the SDM process.

Breaking down the problem will help decision-makers understand the context and definition of the problem. This approach identifies the elements of a decision and helps to turn a complicated problem into a set of smaller more manageable problems[1]. To decompose a problem, we need to do the following:

4. Identify how this decision-problem relates to other decision contexts.
5. Break the problem into its constituent elements:
    - What is influencing the problem (causes and drivers)?
    - What are the actual or potential impacts of the problem?
    - What other problems need to be addressed to solve the problem at hand?
6. Identify limitations and opportunities of the problem and its constituent elements:
    - Biological, legal, logistic, and/or socioeconomic constraints and opportunities.
7. Identify who needs to be involved in the decision.
8. Identify stakeholders related to the decision context.
9. Identify which information or data are available to understand this problem.

Step 2: Set the Objectives

Once the problem is defined, the next step in the SDM process is to set the objectives. Objectives are specific and quantifiable outcomes that relate directly to the management problem and should also reflect the values of stakeholders and decision-makers[2]. Objectives are necessary to identify alternatives and evaluate the impact of management strategies[6].

Step 2 is critical to the SDM process and often overlooked. It can be used to articulate science-based goals, while considering political feasibility[7].

The objective statement needs to articulate the management goal as an expression of public value, not the personal values of decision-makers. It can often include a verb that indicates the desired direction of change (e.g., minimize, maximize, reduce, increase, maintain)[5]. Such verbs can be omitted if controversial and if the desired direction is clear.

Objectives will be the basis for evaluating later steps of the SDM process, so they need to be context-specific and relevant for the decision (based on step 1: defining the problem). The SMART criteria is useful for setting objectives (see Box 2)[4].

The following steps can be used to set objectives for SDM:

1. Brainstorm the "things that matter."
2. Make a list of possible objectives.
3. Separate objectives into means and ends (Figure 2).
4. Test your objectives against the SMART criteria.

For brainstorming objectives, it is important to include a broad cross-section of people who are interested in the outcome of the decision. Some questions that can guide this exercise include the following: What are we trying to achieve by making this decision (or revising this policy or plan)? What are the big categories of desired impact? What would stakeholders be concerned about? The ideas generated by answers to these questions will guide the process for stating the objectives.

The brainstormed ideas must then be turned into concise objectives. Objectives need to contain the most relevant expected results or priorities (i.e., "The things that matter") and the direction we would like to move, such as more (maximize) or less (minimize). Maximize and minimize are used to clarify the preferred direction of change[5].

Often, the objectives that arise during brainstorming may be means objectives (things that we can do to reach a goal) rather than the fundamental objectives (the actual goals). A mapped hierarchy of objectives can assist in separating "means" from "fundamental" objectives by identifying the step-by-step processes that can obtain the desired fundamental objective(s). An easy way to sort between fundamental objectives and means objectives is by asking two questions for each objective: (1) Why is that important? and (2) How can we accomplish that?[2]

Box 2: SMART Objectives

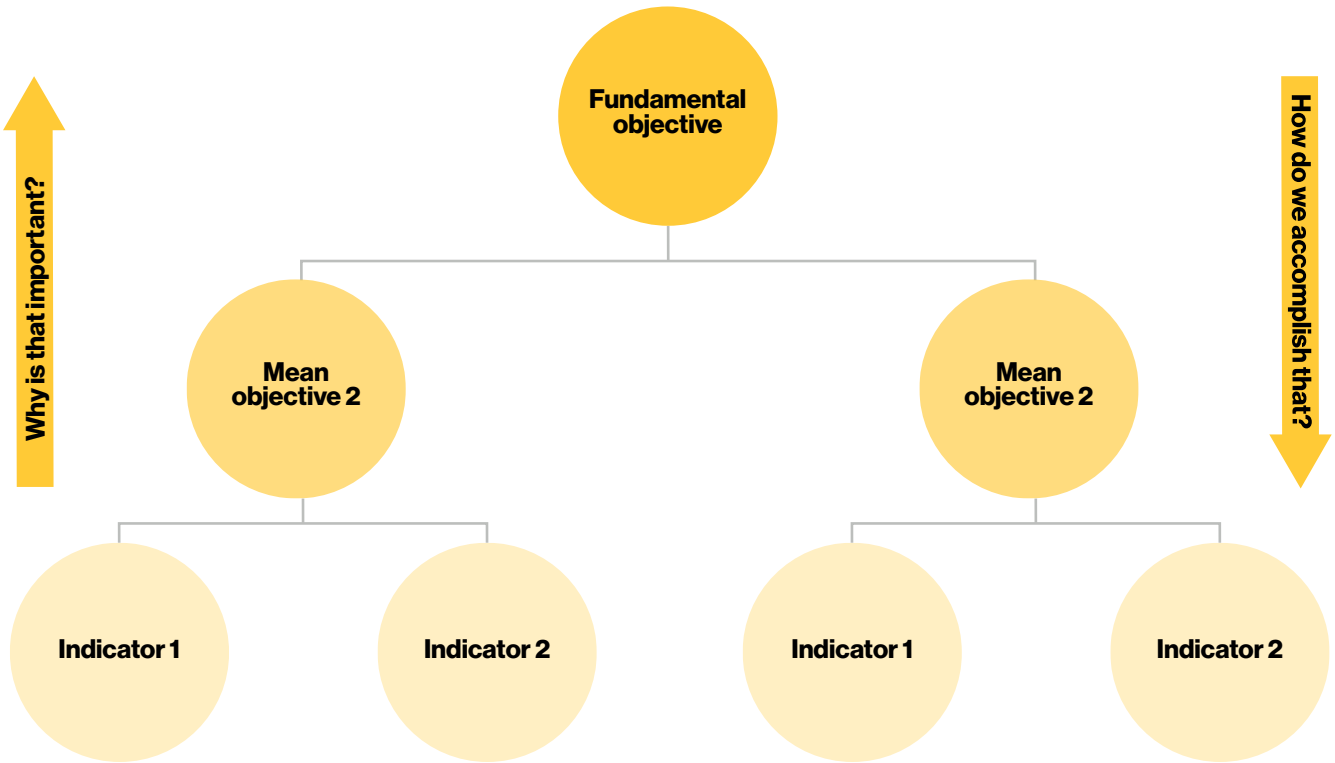
- **S**pecific – A clear definition of exactly what we want to accomplish so that all people involved in the project have the same understanding of what the terms mean.
- **M**easurable – Defined using a standard scale (numbers, percentages, fractions, or all/nothing states) to track the progress toward achieving the objective.
- **A**chievable – Practical and appropriate for the project site and within the political, social, and financial context.
- **R**esults-oriented – Describes necessary changes in target conditions, threat reduction, or other key expected results.
- **T**ime-limited – Achievable within a specific period, generally 1–10 years.

Objectives that answer the question “Why is that important?” with “Because it is” or “Because it is what is desired” are fundamental objectives and are displayed at the top of the map. The next level of hierarchy – means objectives – correspond to objectives for which the answer to the question “Why is that important?” is “Because we need to do this to get to Y” or “Because achieving this leads to what is desired” (see Figure 2). This objective hierarchy is particularly helpful when dealing with multiple fundamental objectives, because it can assist in considering the relative importance of multiple objectives[2].

Indicators should be established during the objective setting process. These are measurable or observable variables used to assess progress toward achieving objectives. Indicators are important for several stages of the SDM process, including during defining the problem, evaluating alternatives, and monitoring implementation[4].

Finally, potential objectives should be iteratively improved by testing whether they meet the criteria that make them useful – that is, SMART, or specific, measurable, achievable, results-oriented, and time-limited (see Box 2).

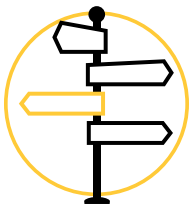
Figure 2. Hierarchy of the objectives



Ask these questions to test if the objectives meet the SMART criteria:

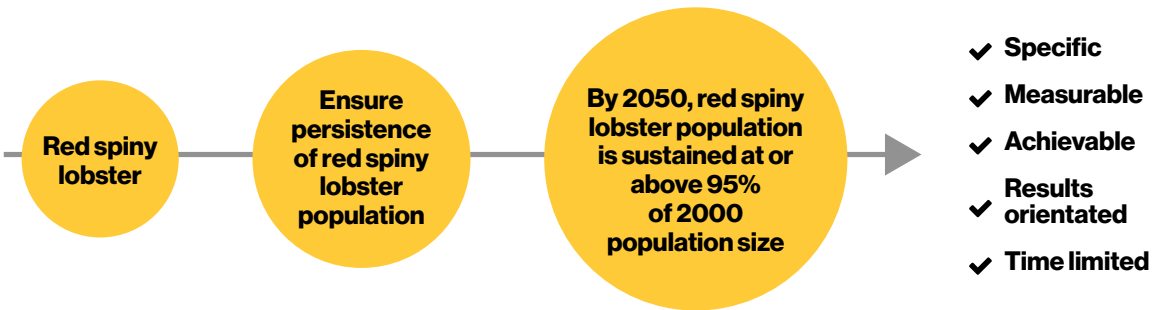
- Specificity. What needs to be accomplished? Why is it important? Who is involved? Where will it take place? How will it be done?
- Measurability. Can the objective be quantified or observed in some way? Is there a way to track progress or measure success using concrete indicators or metrics?
- Achievability. Is the objective feasible given the available resources, time, and expertise? Are the necessary resources, such as funding, personnel, and equipment, available to achieve the objective?
- Results-Oriented. Is the objective aligned with the broader objectives and strategies of the conservation initiative? Does it contribute directly to the desired outcomes and impacts?
- Time-Limited. Does the objective have a clear deadline or timeframe for completion? When does the objective need to be achieved?

Step 3: Consider Alternatives



An alternative is an action, or set of actions, that could potentially achieve an objective if a decision-maker chose to implement it. To define the alternatives, we consider existing actions, previously considered actions, and anything else that decision-makers can think of. Alternatives should reflect substantially different approaches to a decision-problem based on different priorities across objectives and should present decision-makers real choices[5]. Alternatives must reflect fundamental values of the decision as stated in the objectives. They should be based on a sound analysis of the best available information, be clearly defined (so that they can be compared with other alternatives), and aim for quality over quantity (a small number of alternatives iteratively refined).

Figure 3. Example of iteratively improving an objective by testing it against the SMART criteria



The steps to identifying alternatives combines individual and group thinking[2]:

1. Brainstorm potential alternatives (management strategies):
    - Consider individual alternatives by encouraging individual thinking among stakeholders.
    - Refine alternatives identified individually in a group session (group thinking).
    - Keep a record of the alternatives identified individually and by groups.
2. Combine and organize options into fully specified alternatives.
3. Define the alternatives that will be analyzed in upcoming steps. This is an iterative process that can be achieved by consensus rounds.

Identification of alternatives should be creative and unconstrained by perceived feasibility. Creative thinking about possible alternatives can provide decision-makers with options that fulfill objectives and institutional needs while dealing with uncertainty. Additionally, when you consider alternatives, objectives can have a reasonable chance of being implemented on time and within budget[5].

Step 4: Identify Consequences

The next step in the decision-making process is to evaluate how each alternative will perform to achieve the objective(s). Identifying the expected consequences of an alternative provides critical information to understand and compare the advantages and disadvantages of choosing each alternative and their related uncertainties.

For this step, it is key to include in the decision-team someone who clearly understands the system. Consequences can be identified by using available knowledge; analyses by data scientists, economists, ecologists, or other relevant practitioners previously identified; and/or through predictive use of modelling[5]. These consequences should be later discussed and validated by relevant stakeholders[5].

A useful approach to analyze consequences is through criteria-based comparisons (i.e., ranking tables or consequence tables). This approach involves rating each alternative across a set of criteria (i.e., potential impact, riskiness, feasibility – financial or technical – fit, and gap)[4].

A consequence table can be used to rapidly summarize how

Galápagos National Park staff member Javier Chafla during Lenfest SDM workshop

Photo credit, Leah Gerber

the performance of each alternative relates to each objective. The complexity of the consequence table will depend on the problem and the depth of analysis required. It can be based on a qualitative ranking or weighting system or a more quantitative approach (see Table 1). Table 1 considers objectives by row with different alternatives across the columns. The anticipated consequences for each alternative are considered in relation to the specified objective, and a representation of the relative consequence for each alternative is entered in the cells. These predictions of consequences should make the most of available information and incorporate uncertainty[6].

Table 1. Example of a Consqueqnce Table

Objective	Evaluation criteria (measurable attribute)	Alternative 1: Do nothing	Alternative 2: Increase number of individuals (repopulation)	Alternative 3: Manual removal of invasive algae
Conservation: Minmize coral losses	Coral cover area	x% of cover	xx% of coverage	xxx% of cover
Economic: Minimize cost	Average annual addition cost to the GNPD	0	$ more	$$ more
Social: Maximize the positive social impact of conservation interventions.	Increased economic opportunities (i.e., tourism in coral areas)	Low	High	Medium

Step 5: Determine Trade-offs

Making a choice among alternatives will generally require a decision-maker to assess the trade-offs of consequences across the objectives. In rare cases there will be an alternative that provides a clear advantage in providing benefits across objectives. However, most contexts of decisions will involve trade-offs of some kind, in which the decision-maker must decide how to best balance gains in one objective against losses or no change in benefit for another objective (e.g., costs vs. coral cover, in alternatives in Table 1).

SDM does not prescribe how a decision-maker should weigh these trade-offs. It provides only a process for laying out the information necessary to make the trade-offs across choices clear. This acknowledgement of trade-offs in decision-making provides transparency around the gains and also the losses (real, potential, and perceived) that could be delivered by the different alternatives to be considered[8].

Tools are available to help decision-makers visualize and order trade-offs. These approaches can be qualitative – such as an elicitation round among the decision-team to compare pairs of alternatives – or quantitative, using tools such as prioritization, direct rankings (i.e., assigning a performance score to an alternative), and value models (calculating the performance score of an alternative)[5].

Step 6: Implement Decision and Monitor

The prior steps led to identification of alternatives that are expected to be successful given current knowledge of the system and levels of uncertainty. The implementation of these alternatives does not guarantee good outcomes, but it should result in the best outcomes available for the context. Additionally, implementing a selected alternative can improve the chances of future success by informing learning[6].

A decision-maker implements an alternative within the context of how their organization executes policies and procedures[4]. Part of implementation is to identify mechanisms for ongoing monitoring that can ensure that on-ground actions are achieving the objectives as anticipated. Monitoring the performance of an implemented alternative against the objectives can also improve the information available for future decisions and provide a review mechanism so that new information can be incorporated into future decisions.

The Galápagos islands are a popular destination for ecotourism, and spatial management of impacts is a high priority for the GNP

Photo credit, Leah Gerber

For SDM to be effective, the learning component is key (see Figure 1, step 6). One can learn by monitoring the indicators of the implemented actions. The design of a monitoring strategy needs to provide information that can update the understanding of consequences. Monitoring should be designed to measure how the alternatives are performing in relation to the different objectives and provide managers with information they can use to determine whether to continue implementing the current alternative or find something more effective.

In general, this step of the SDM process promotes learning over time and provides opportunities to revise objectives or alternatives based on what is learned[5].

Lenfest team member Dr. Susana Cardenas discussing data to decisions approach during Lenfest SDM workshop

Photo credit, Leah Gerber

Lenfest team member, PhD candidate Paola Sangolqui assisting during sea cucumber population monitoring led by the Galápagos National Park Directorate

Photo credit, Paola Sangolqui

Section 2: How Can an SDM Approach Support Decision-Making in the Galápagos Marine Reserve?

The application of decision theory to marine reserve management is complex. Like many natural resource management contexts, marine reserves often have multiple management objectives, costs, and benefits accruing on different scales; there can be uncertainty about the efficacy of possible alternatives, and the agencies that implement conservation are generally resource constrained. This can lead decision-makers to disagree on what the best decision may be.

The Galápagos Marine Reserve (GMR) is one of the most recognized and studied marine protected areas due to its unique natural features and high species endemism, which makes it a priority region for conservation[9]. It extends 40 nautical miles from the base line of the archipelago and covers approximately 142.000 km2. Besides the ecological and scientific importance of the GMR, its natural capital is the base of the insular economy. In 2014, the "Management Plan for the Well Being of the Galápagos Protected Areas" was released, integrating the management of the National Park with the Marine Reserve and defining the Galápagos as a socio-ecosystem. However, this plan does not include a decision-making framework that specifies conservation targets, measurable objectives, or strategies that link monitoring data to decisions.

The GMR faces challenges that can interfere with decision-making effectiveness[10]. The impact of management decisions on protected areas needs to be assessed to provide continuous feedback to support the decision-making process. To achieve this, strategic planning needs to be deployed in concert with an effective monitoring and evaluation program.

The Galápagos National Park Directorate (GNPD) identified a set of annual activities to accomplish their stated objectives, which are described in the Annual Operating Plan. This plan frames internal objectives with associated activities. However, it does not generate the desired impact in achieving the management plan's objectives and is not clearly linked to the fundamental objectives of GMR management[11].

Box 3: Benefits of SDM to the GMR

- Add transparency to decision-making processes.
- Improve communication among stakeholders (i.e., participatory management)
- Provide a clearer connection between decisions taken and their expected impact on achieving objectives.
- Deliberately incorporate institutional memory into the decision-making process (i.e., lessons learned from the participatory process of the management plan and zoning)
- Optimize use of resources (i.e., establish monitoring programs that collect relevant data to inform the stated objectives.)

As a recognized socio-ecosystem, participatory processes in the Galápagos have played an historical role in decision-making for protected areas. However, a sense of disempowerment by the local community[12], lack of institutional trust, and community disengagement have been repeatedly reported. These troubles have been attributed to a lack of continuity in participatory processes, policy shifts related to governmental

changes, and discontinued funding[12,13]. There is also a local perception of participatory processes as a top-down "required" exercise, rather than a valued process, which has also caused a lack of progress and engagement[12]. This has resulted in several documents and reports[11,13] that indicate a low index of institutional trust in the Galápagos province (5.8/10), placing it below the national average.

The Galápagos Sustainable and Urban Development Plan for 2030[13] highlights the promotion of a strengthened and organized institutional decision-making structure as a key step for local governance. This plan also emphasizes the importance of stakeholder engagement in the decision-making process and development of monitoring plans for the Galápagos[10].

There have been extensive calls for community/stakeholder engagement at the earliest stage of the decision-making process. This includes engaging in knowledge co-production and knowledge exchange (during data collection, such as determining research questions and objectives), learning stakeholder priorities, understanding the socio-cultural and institutional contexts in which collaborating partners operate, increasing transparency and accountability, and building trust in the early research phases leading up to decision-making.

Management strategies have been developed by the GNPD to address the situation described above, but they have not been adequately implemented due to institutional constraints. Such constraints include deficient design of organizational structure; insufficient availability of human, physical, and financial resources; lack of communication; and the absence of a monitoring and evaluation system with status, pressure, and response indicators of a system to support decision-making[11].

Addressing these challenges calls for a clear and transparent framework that supports participatory processes, decisions that can be maintained over time, and stakeholder participation in the full cycle of decision-making, irrespective of political cycles. SDM provides a rigorous framework to identify interventions that are most likely to achieve stated management objectives. We next discuss how the steps of the SDM process could assist the GNPD in overcoming these challenges.

Define the Problem

Because the GMR is a multi-purpose reserve with multiple stakeholders, starting each decision-making process by formally defining the problem would help provide necessary structure for the decision-making processes of the GNPD.

Defining the problem allows the identification of key stakeholders, involving sectors that may not be sufficiently represented or absent from decision-making processes. The Galápagos Special Regime Law calls for a "consultative management board" that has not yet been implemented. The use of the SDM as a decision-making tool would provide an opportunity to promote participatory and transparent processes that could encourage the activation of the "consultative management board."

In addition, given the budget constraints in the GNPD, well-posed decision problems would support institutional planning for human resources, fund requirements, and annual activities. Clearly defined problems enhance the optimization of resources and guide the alternatives and analysis at later stages.

Set the Objectives

Ensuring that clear, well-defined objectives are identified for each decision-making process gives managers direction and an ability to identify the strategies for achieving their goals. The GNPD has an "Annual Operative Plan" (2014), in accordance with the management objectives of the management plan. For each objective, the management plan establishes specific strategies, and each department develops activities to fulfill these strategies. However, there are two limitations to this model.

First, the objectives tied to current strategies are at a very high hierarchical level, and the route to achieve these objectives is unclear. In addition, these objectives do not meet the SMART criteria, which makes them difficult to monitor, measure conservation outcomes, and evaluate management efficacy. For example, one of the stated objectives of the Conservation Zone (e.g., artisanal fishing exclusion) is to "ensure the sustainable use of ecosystem services, particularly those of regulation and cultural services"[14]. This objective is not measurable, thus not an effective operational tool for management.

Second, the GNPD currently lacks a department in charge of monitoring the efficacy of their management strategies. The GNPD issues an annual management report that evaluates compliance with planned activities based on management indicators. However, there is confusion between monitoring compliance with planned activities versus monitoring the effectiveness of these activities and the extent to which they contribute to the fulfillment of management objectives. Indicators are not defined for most of their monitoring programs, and it is not clear how data that is collected is informing decision-making.

Consider Alternatives

Broad consideration of alternatives gives managers the opportunity to identify creative ways to achieve their objectives. In the GNPD, as in most environmental management institutions, alternatives tend to consist of ongoing funded projects. It is not clear how these ongoing projects are contributing to the fulfillment of objectives or how they can be assessed for effectiveness. This limited set of alternatives often fails to address a full range of multiple objectives, deal with uncertainty, or be implemented on time and within budget.

Iterating new and potentially better strategies could help to find solutions to achieve the GNPD fundamental objectives. In addition, exploring new alternatives can help the GNPD explore and compare trade-offs among different actions and make better informed management decisions.

Identify Consequences

This step includes evaluating the effects of alternatives in terms of how well they can achieve the objectives; these can include expected impacts on things, such as biodiversity, habitat quality, species populations, ecological processes, and/or socio-economic aspects. By quantitatively and qualitatively assessing these impacts, decision-makers can better understand the potential consequences of their choices and prioritize actions that minimize negative impacts and enhance positive outcomes.

Implementing this stage in the GNPD's decision-making process would facilitate informed decisions that include

stakeholder participation. Stakeholder participation at this stage ensures a comprehensive understanding of the potential impacts of alternative actions. Involving stakeholders, such as fishermen, provides valuable insights into the socio-economic aspects and user perspectives related to the decision-making process. Their input helps to capture a broader range of consequences, refining the assessment of impacts on biodiversity, habitat quality, and other relevant factors. This participatory approach ensures that the consequences considered are not only scientifically grounded but also incorporate the practical experiences and concerns of those directly affected by the decisions, contributing to a more robust decision-making process.

For example, fishermen indicate that the information available at the GNPD is not sufficient to make an informed decision about opening or closing a sea cucumber fishery. This step of the SDM approach elucidates how different alternative actions influence their set of management objectives. Understanding this influence could be based on analysis of spatial, economic, social, biological, and ecological data depending on which objectives are deemed important. By considering these measures in a consequence table or model, decision-makers can lay out the consequences of different options that will be further evaluated in the next step of the process.

Determine Trade-offs

Identifying how different alternatives perform in terms of the objectives gives managers the ability to consider how choices they might make could result – or not – in balancing the competing desires in their system. The Galápagos Islands are recognized as a socio-ecosystem11 where conservation and development are integrated. Such complex systems that involve multiple-objectives and interests (i.e., biodiversity conservation, tourism, fisheries) will likely encounter complex trade-offs that need to be assessed for selecting effective alternatives. For example, decision-makers may consider trade-offs in zoning marine areas for tourism, fishing, or protection.

Evaluation of trade-offs should be involved in the design, planning, decision, and implementation of conservation-development decisions. Understanding the trade-offs helps to ensure that the resources (i.e., money, time, human resources) are being used wisely. Recognizing trade-offs could add accountability toward democratic and transparent decision-making processes in the GNPD[15].

Implement Decision and Monitor

Finally, managers must implement a decision, but the decision support process does not need to stop there – observing the outcomes of the decision is very useful for supporting future decisions. The Galápagos National Park's management plan is characterized as an adaptative plan[11]. A structured decision-making framework is the foundation for developing a formal adaptive management plan[16].

The GNPD currently has several monitoring programs where monitoring seems to be the main objective[11]. To support decision-making, monitoring impacts of actions needs to provide information that is needed for the decision – such as evaluating the effectiveness of the strategies implemented and their contribution to meeting objectives[16]. By doing so, the budget can be optimized and managers can learn about the system to reduce uncertainty in future decisions. Following an SDM approach could assist the GNPD in reframing their monitoring programs' objectives, scope, and periodicity and align them to inform decisions.

Galápagos sea lions are an emblematic species in Galápagos ecotourism

Photo credit,
Juan Carlos Figueroa

Whimbrel, a migratory bird in Tortuga Bay beach

Photo credit,
Leah Gerber

Section 3: Case Study for Applying SDM in the Galápagos Marine Reserve

The case study presented in this handbook was selected during a workshop held in Puerto Ayora, Santa Cruz, Galápagos at the Galápagos National Park Directorate (GNPD) headquarters in April 2022. The workshop was jointly organized by ASU, WildAid, and the GNPD.

The purpose of this case study is to illustrate the steps of a Structured Decision-Making (SDM) approach in an ongoing decision-making context. We aim to outline a general approach to work through each step of the SDM framework for a case study, which can be followed to address other decision problems faced by the GNPD.

To select the case study, we conducted an exercise that involved brainstorming potential problems requiring intervention from managers. We then analyzed whether these situations warranted an SDM approach (see Box 1). Considering the available data and the environmental, social, economic, and political aspects, we ranked the cases to determine their importance and urgency in solving the problem (see Appendix 1). Through this exercise we identified two options for implementing an SDM case study (Sea cucumber fishery or Longline fishery). Both options were presented to the director of the GNPD. After assessing the feasibility of conducting each case study, we selected the sea cucumber case study. We walk through the steps of the SDM process for the seacucumber fishery below

Step 1: Define the Problem

This step is key to understanding the decision context. This includes identifying the reason a decision needs to be made and who needs to be involved in the development and implementation of solutions.

What is the nature of the decision?

We identified two sea cucumber fishery management decisions that would benefit from applying an SDM approach:

- Decide which type of monitoring to implement to track sea cucumber population status in a way that can be used to inform fishery management choices.
- Decide what circumstances should determine whether a sea cucumber fishery could be opened (e.g., catch quota, spatial management).

Who needs to be involved?

To identify relevant stakeholders, we first considered the nature of the problem we were trying to solve, the main concerns about the resource, and who could influence the outcome. Stakeholders were considered as those actors who held data, could contribute knowledge, and/or had the authority to make the decision in the given context.

The designated personnel of the GNPD identified the main stakeholders for sea cucumber management.

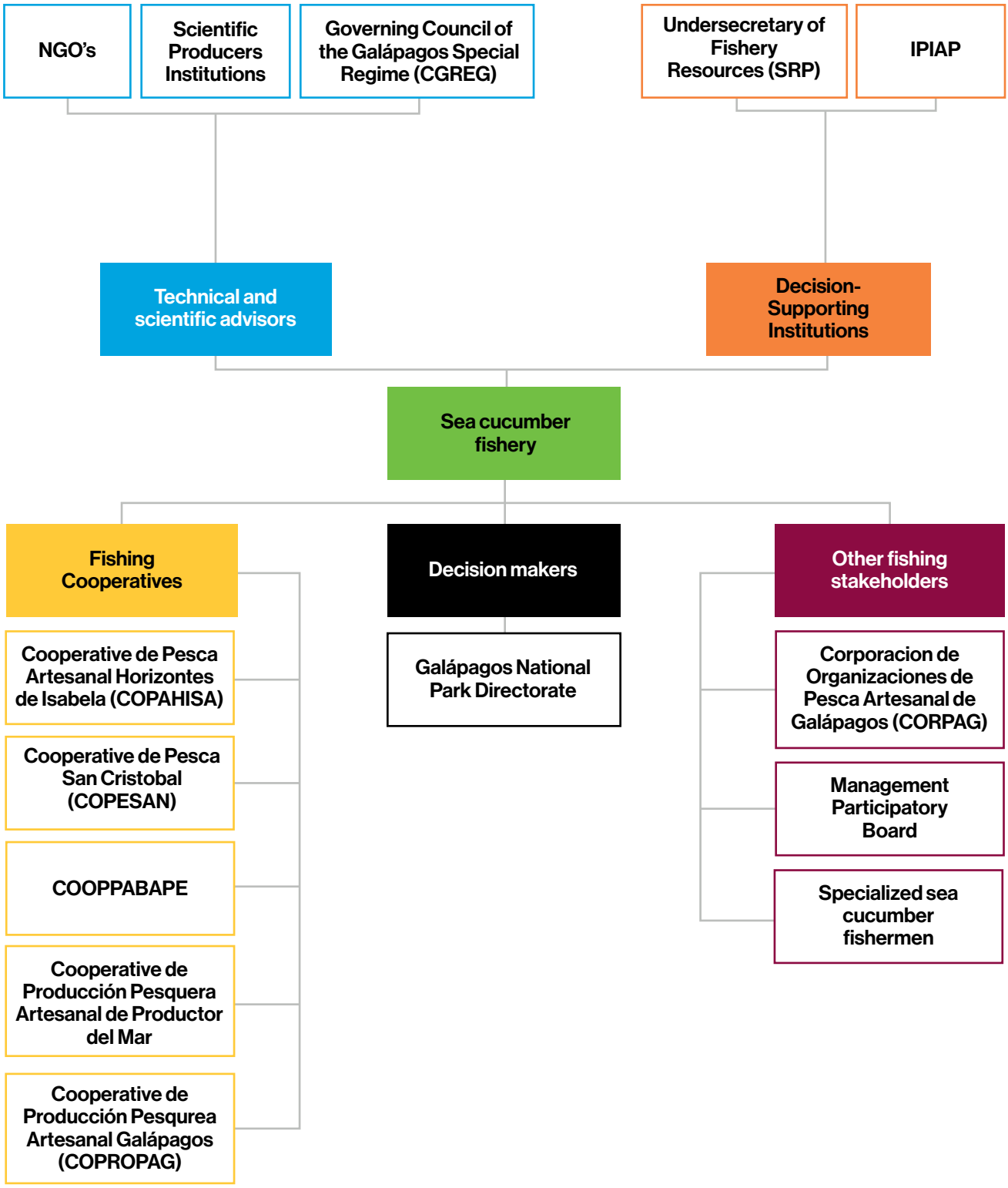
Furthermore, in later workshops for constructing the fishing calendar, we collected information from fishing cooperatives and other stakeholders to refine the list of relevant stakeholders. We then used all this information to create a stakeholder map (see Figure 4) that grouped stakeholders according to their function.

Making sure all relevant stakeholders are involved is key for achieving the expected outcomes of the decision; for example, during the workshops, lack of representation of the fishing sector was identified. To date, only leaders of certain unions (e.g., fishing cooperatives) were included in decision-making processes, which excluded stakeholders who were not obliged to join or who did not feel represented by the leaders of certain unions. As part of the agreements achieved during the workshop, the fishing cooperative leaders agreed to discuss the information with the fishing sector; however, there is not a way to enforce this. Therefore, the need to include representation from a broader set of stakeholders is a key consideration going forward.

Blue sea star

Photo credit,
Leah Gerber

Figure 4. Key stakeholders identified for the sea cumber fishers management



Formulating a clear problem statement

A clearly defined problem is a critical step for decision-making. The Galápagos Marine Reserve faces the challenge of making critical decisions regarding the management of the sea cucumber fishery. The need for these decisions arises from the complex nature of the ecosystem and the importance of balancing ecological sustainability with economic interests. We summarized contextual information in a situation model to help to frame the problem statement that represents the decision.

Sea cucumber population trends

In the Galápagos Islands there are 38 species of sea cucumbers, but the only species fishermen are legally authorized to harvest is the brown sea cucumber (Isostichopus fuscus). I. fuscus is one of the most common species in the Eastern Pacific, and it used to be the most conspicuous invertebrate in the shallow subtidal zone in the Galápagos Islands. However, in the early 2000s its overexploitation led to a total closure of the Marine Reserve for five (5) years between 2016 and 2021. The International Union for Conservation of Nature (IUCN) has classified I. fuscus as "endangered"[17] and the Convention on International Trade in Endangered Species (CITES) has included it in Appendix III.

Figure 5. Annual Densities From *I. fuscus* Since 1992 to 2022 in the Galápagos Marine Reserve (Source: DPNG, 2022)

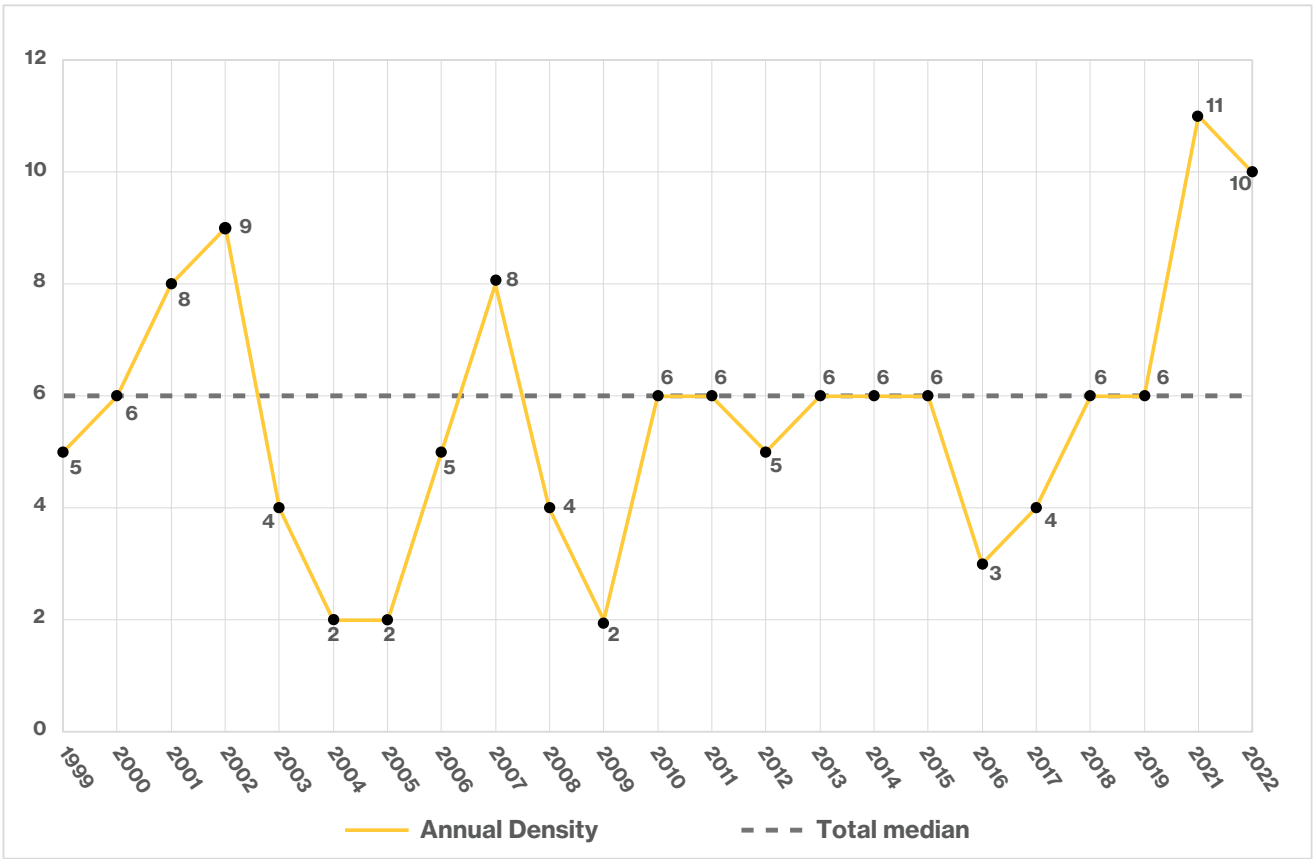


Figure 6: Situational Model for *I. fuscus*

Development of a research and monitoring program

Promote a transparent and fully participatory co-development of the fishing regulations

Fishing regulations

Strengthen law enforcement and the use of technology to optimize control and surveillance actions.

Develop a collaborative framework to enhance institutional capacity by fostering national and international cooperation

Lack of evidence-based fishery management

- Ineffective communication and information sharing among stakeholders
- Outdated monitoring (data quality) and analysis methodologies

Socio-cultural aspects

- Low awareness of non-fishers stakeholders
- Weakened organizational structure within fishing associations
- Inadequate development of financial literacy within the fishing sector

Poor compliance with fishing regulations

- Low awareness of judiciary prosecutors
- Poor harmonization of existing regulations (resolutions vs. law)
- Insufficient control and surveillance in situ to ensure compliance
- Lack of knowledge of regulations and impacts of non-compliance
- Local laws not articulated with other laws that dictate the management of fishery resources.

Economic drivers

- High international market demand
- Lack of profitable alternative livelihoods

Institutional constraints

- Insufficient public funding for management strategies
- Unclear synergies and roles with other relevant institutions
- Lack of sufficient technical staff (fisheries management skills)
- Low institutional trust from stakeholders
- Political interference in decision-making

Unsustainable fisheries

- Illegal, Unreported, and Ungregulated (IUU) fisheries
- Overfishing by small-scale fisheries

Weakened marine management

- Weak sanctioning framework

Climate change

The Galapagos Marine Reserve

Sea cucumber

▲ 2 goals

Ecosystem services

- Food and feed (fishing)
- Carbon sequestration
- Nutrient recycler

Human well-being

Livelihood for local community fisheries

Legend

- Strategies
- Contributing factors
- Direct threats
- Conservation target
- Ecosystem services
- Human well-being

Sea cucumber management in the Galápagos has historically considered population density as the key indicator for decision-making. The estimated abundance of sea cucumbers in the Marine Reserve was estimated at approximately 30.4 million individuals in 2022[18].

Situation model to identify the drivers of sea cucumber population trends

Identifying the physical, biological, and social stressors that influence the I. fuscus population decline is key to effective management of the species. I. fuscus stressors include fishing pressure, water temperature, nutrients, and anthropogenic stressors. We developed a situation model to visualize these factors and possible management actions to mitigate them. Figure 6 shows the direct threats, contributing factors, and management strategies for I. fuscus.

Available data and information to inform decisions related to I. fuscus

We explored the information and data available to better understand the context. Identifying the data available helps to plan next steps and identify other relevant information to potentially collect.

Sea cucumbers are one of the most important fishing resources in the Galápagos19–22. The GNPD has been collecting sea cucumber data since 1999. While the collected data have historically informed decisions related to I. fuscus in the Galápagos, it is essential to acknowledge the existing gaps in information. In particular, there is a call for other relevant data, such as reliable Catch Per Unit Effort (CPUE) per fishing zone, to enhance the comprehensiveness and accuracy of resource management strategies. There also remains a need for greater clarity regarding other socio-economic aspects and the standardization of data collection methods.

The following list reflects available data that has historically been used for I. fuscus management:

- Research and Fishing Participatory Monitoring Program database of the Charles Darwin Foundation, the GNPD, and the fishing sector of Galápagos;
- Sea Cucumber Population Monitoring Program database of the GNPD and the fishing sector of Galápagos;
- Fishing dataset from the GNPD (only available during the years when the fishery was opened);
- Landing Ports Monitoring (only available during the years when the fishery was opened);
- Sampling with fishing boats captain's logbooks (2000–2001).
- Onboard observers (1999–2005).

Local Regulatory Framework

In the situation model, we identified "Poor compliance with fishing regulations" as a contributing factor for unsustainable fisheries. In the Galápagos Marine Reserve, the legal framework governing fisheries in the province is outdated. In 2023, a five-year fishing calendar was approved after an extensive review period. However, the fishing law has not been updated for the past 15 years, and its framework relies on a special law that no longer exists (this law is expected to be updated this year). Furthermore, the 2016 zoning plan has failed to be implemented. When regulations do not align with current ecological, technological, and socio-economic realities, they may fail to address emerging challenges or opportunities within the fishing industry. This lack of relevance can result in confusion among stakeholders, diminishing their understanding of the rules and reducing their motivation to comply. Additionally, outdated regulations may not reflect advancements in sustainable fishing practices or changes in the ecological status of marine resources. This discrepancy between regulatory requirements and the actual context may foster a culture of non-compliance, as fishermen may perceive the rules as obsolete or unjust. Ultimately, the ineffective enforcement of regulations within an outdated framework jeopardizes the sustainable management of fisheries, putting the targeted resources at risk of over-exploitation and long-term degradation. Updating and adapting regulatory frameworks to current circumstances is crucial to ensuring effective compliance and safeguarding the sustainability of marine ecosystems. The sea cucumber fishery is regulated by the following policies: Special Regulations for fishing activities in the Galápagos Marine Reserve of Galápagos, Five-year fishing calendar, Resolutions for opening the fishery.

Problem Statement:

Given the context detailed above, we formulated a problem statement to define the decision-making needs for this situation.

The GNPD is confronted with a critical challenge in making informed decisions for the management of the sea cucumber fishery, particularly in determining when to open or close the fishery based on catch quotas or spatial management. The complexity arises from the need to balance ecological sustainability with economic interests. The overexploitation of sea cucumber (Isostichopus fuscus) led to a five-year closure of the Marine Reserve between 2016 and 2021, classifying it as "endangered" by the IUCN. Despite historical reliance on population density as a key decision-making indicator, there is a pressing need to address gaps in information, specifically in socio-economic aspects and standardizing data collection methods. The outdated local regulatory framework further exacerbates the challenge, with the fishing law not updated for 15 years and a zoning plan from 2016 left unimplemented. Poor compliance with these outdated regulations poses a significant threat to the sustainable management of the sea cucumber fishery, necessitating urgent updates and adaptations to the regulatory framework to align with current ecological, technological, and socio-economic realities.

Step 2: Set the Objective

Improving the sea cucumber fishery management involves many potential strategies and activities. Determining the fundamental objective(s) associated with a decision around the problem of how to decide when to open the fishery involves assessing the goals and concerns of relevant stakeholders and asking what, why, and how questions to sort out what is important. In Table 2 we propose a path to identify the what, why, and how questions prior to setting an objective.

Based on this exercise, the fundamental objective in this context is to maintain sea cucumber populations within the Galápagos Marine Reserve at a level that sustains several individuals capable of supporting fishing into the future. A formal statement of the fundamental management objective should adhere to the SMART criteria (see Figure7).

Figure 7. Example of a Management Objective for I. fuscus that follows the SMART Criteria

Example if a possible management objective for *I. fuscus*

By 2026, the population if *I. fuscus* is sustained at or above the abundance at maximum sustainable yield while also providing profitable income to local communities.

Smart ✓	Measurable ✓	Achievable ✓	Results Orientated ✓	Time limited ✓

Once the objectives are clear, the cost and benefit data management tool (see Section 4) can be used to organize these objectives and make their links with the strategies clear. The second sheet, "Strategies" (see Section 4), specifies how conservation strategies are expected to achieve specific management objectives. This sheet can help answer questions, such as "What are we trying to achieve with this strategy and how?" and "How can we measure the achievement of our objectives?"

Step 3: Consider Alternatives

As outlined in the situation model, the following alternatives are possible actions to explore when considering how to guide decision-making concerning the opening and closing of the sea cucumber fishery. These alternatives all aim to maintain a sea cucumber population that is sustained at or above the abundance at maximum sustainable yield:

1. Development of a comprehensive research and monitoring program;
2. Promotion of a transparent and fully participatory co-development of fishing regulations;
3. Strengthening law enforcement efforts and leveraging technology to optimize control and surveillance actions;
4. Develop a collaborative framework to enhance institutional capacity by fostering national and international cooperation.

We selected the first three key alternatives from the proposed list and developed a result chain for each. A result chain is a conceptual framework that illustrates the logical sequence of steps needed to achieve a

Key

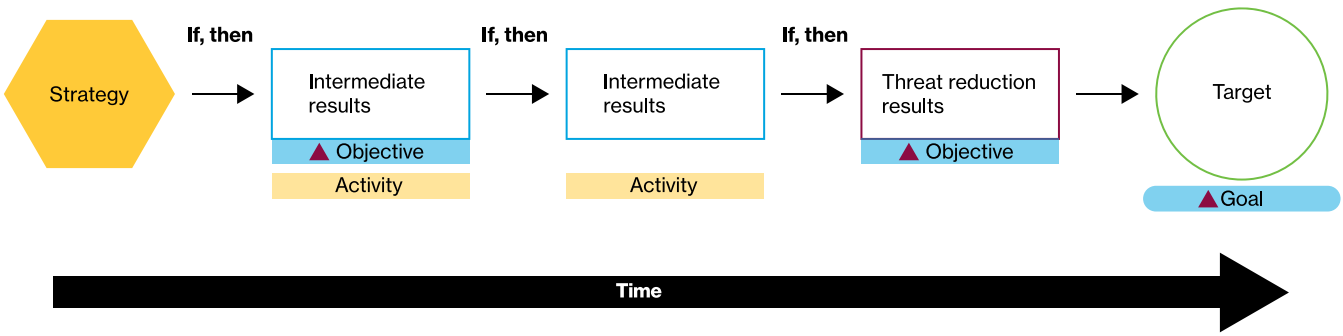


Figure 8: Result chain for three *I. fuscus* Conservation Strategies

7a.

Promote a transparent and fully participatory co-development of the fishing regulations

Establishment of a stakeholder engagement framework for co-development of fishing regulations

Improvement of the communication and information sharing stakeholders

Provide knowledge exchange/ training opportunities

Sea cucumber population increase

▲ 2 goals

8b.

Development of a research and monitoring

Data is available for all stakeholders involved in design process

Updated monitoring and data analysis methodologies

Conduct a thorough evaluation of the existing monitoring and data analysis methodologies

8c.

Strengthen law enforcement and the use of technology to optimize control and surveillance actions

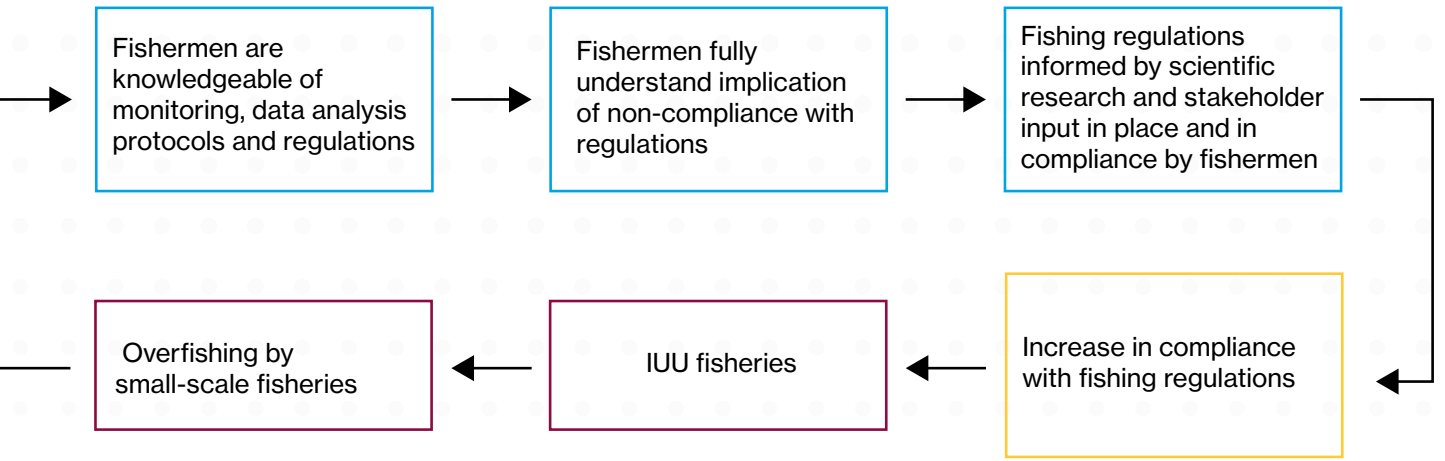
Sufficient personnel, equipment, and funding to conduct patrols

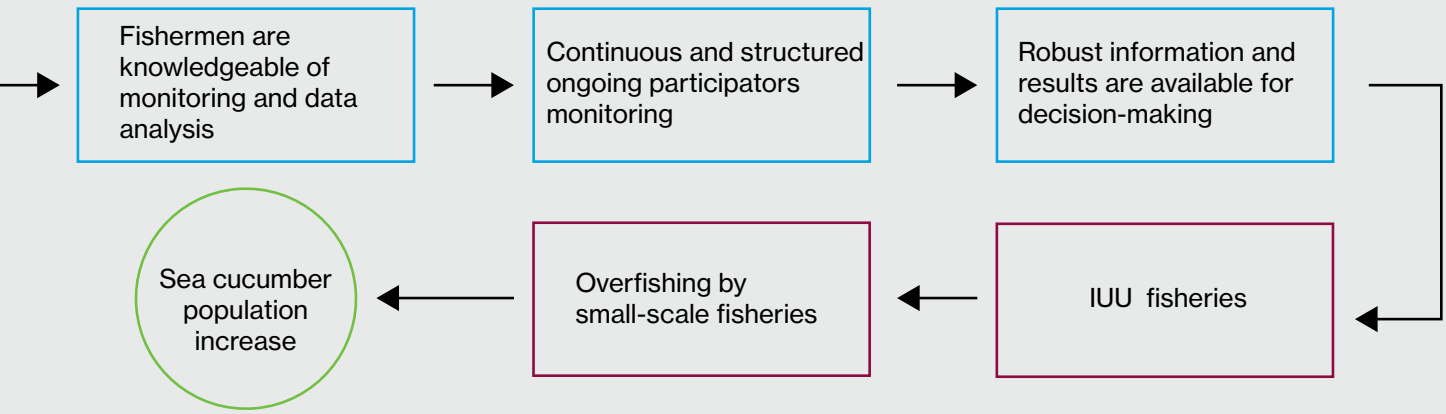
Technology implementation plan in place

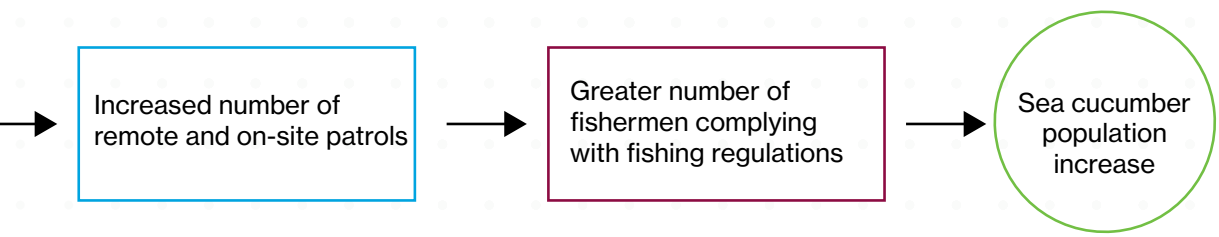
Trained environmental authority puts in place a system for monitoring and analyzing data

Conduct assessment of technological needs

Secure funding for equipment and stakeholder engagement


Fishermen are knowledgeable of monitoring, data analysis protocols and regulations
Fishermen fully understand implication of non-compliance with regulations
Fishing regulations informed by scientific research and stakeholder input in place and in compliance by fishermen
Increase in compliance with fishing regulations
IUU fisheries
Overfishing by small-scale fisheries


Fishermen are knowledgeable of monitoring and data analysis
Continuous and structured ongoing participators monitoring
Robust information and results are available for decision-making
IUU fisheries
Overfishing by small-scale fisheries
Sea cucumber population increase


Increased number of remote and on-site patrols
Greater number of fishermen complying with fishing regulations
Sea cucumber population increase

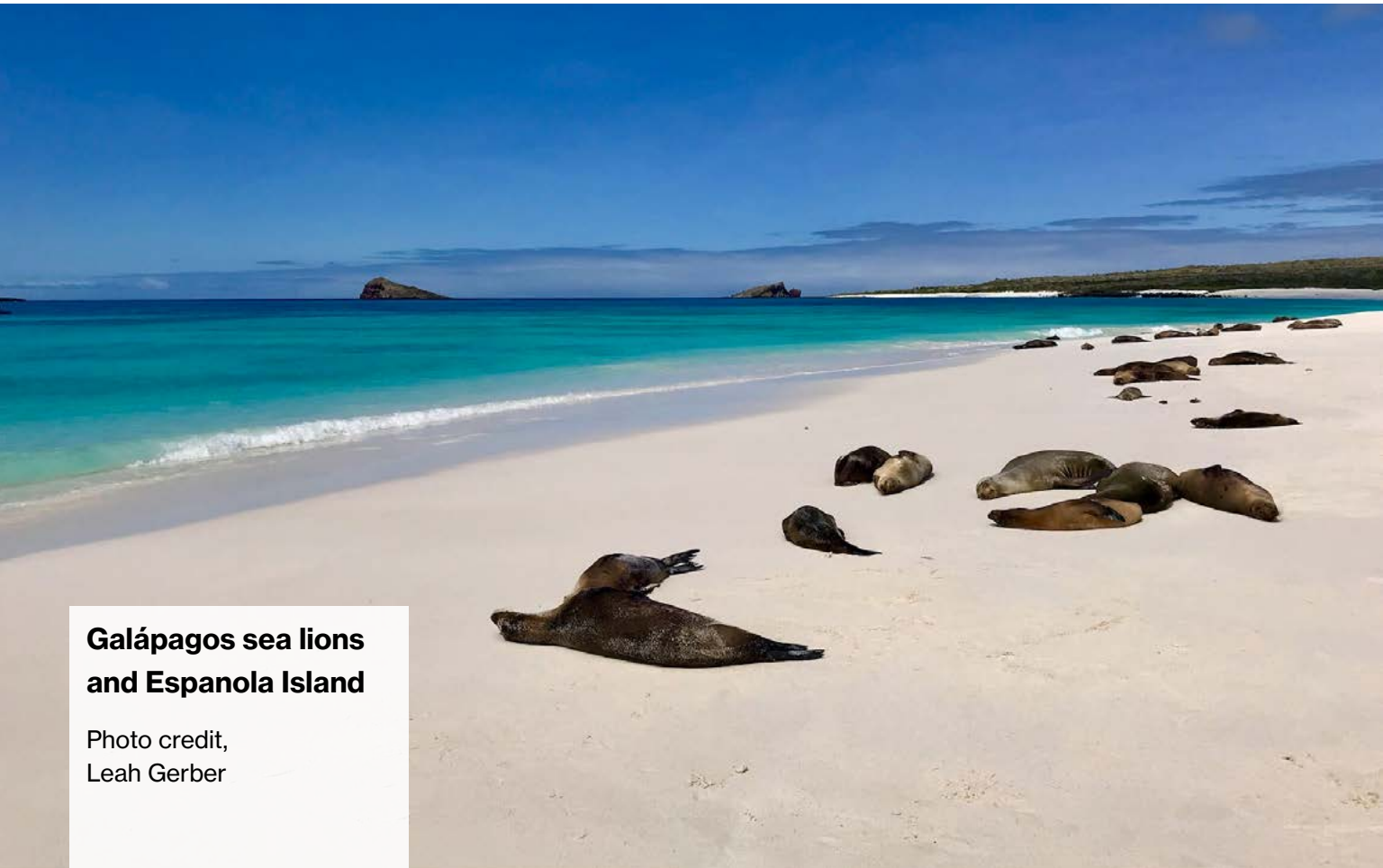
desired outcome toward the accomplishment of the objective set in the previous step. By developing result chains for the chosen alternatives, we aimed to enhance our understanding of the details of each strategy and how they were expected to contribute to the overarching goal of sustainable sea cucumber management in the Galápagos Marine Reserve.

Step 4: Identify Consequences

Predicting the consequences of different management alternatives can be challenging; however, we drew from two sources to evaluate possible consequences. First, this fishery has an historical archive of the fishery activity, and second, studies have been conducted in recent decades to evaluate management strategies or actions for the management of sea cucumber fisheries in other developing countries[23].

We used a consequence table (see Table 3) to organize information on how the proposed alternatives would be expected to perform in terms of achieving the example objective: By 2026, the population of I. fuscus will be sustained at or above the abundance at maximum sustainable yield while also providing profitable income to local communities.

For this step, the cost and benefit data management tool (see Section 4) can compile data about historical costs, progress, and outcomes of the strategies that have been previously implemented to provide information about money spent on each strategy and the efficacy of a strategy in achieving stated objectives.



Galápagos sea lions and Espanola Island

Photo credit,
Leah Gerber

Table 2. Table for Structuring a Management Objective for *I. fuscus*

Goals or concerns of stakeholders	What do we aim to achieve?	How do we aim to achieve it?	Why do we aim to achieve it?	
Decrease in sea cucumber population density	Recover and maintain a healthy population in accordance with the population indicators	Manage fishing activity and/or restore habitat	To continue with a responsible fishing activity	To achieve a population of sea cucumbers that persists into the future
Closure of the fisheries	Sustainable fishing practices to guarantee open fisheries	Fishing calendar	To provide an updated legal framework with an ecosystem perspective	To achieve a population of sea cucumbers that can provide income from the fishery into the future
Unclear indicators for evaluating the sea cucumber population	Revise and update indicator for managing sea cucumber	Identify indicators that provide meaningful inference about population responses to fishing and management actions	To achieve a population of sea cucumbers that can provide income from the fishery into the future	To evaluate the effectiveness of our interventions
Outdated monitoring (data quality) and analysis methodologies to determine the catch quota	Revise proposed ethodologies for collecting and analyzing data	Analyze in a way that can provide meaningful inference about population responses to fishing and management actions	To support management actions that result in sustainable sea cucumber numbers	To achieve a population of sea cucumbers that can provide income from the fishery into the future
Stakeholder lack of trust in the decision process	More acceptance by stakeholders of conservation strategies and alternatives being considered by guaranteeing transparency, representation, equity, and coordination	Promote a transparent and fully participatory decision-making process	To support management actions that result in sustainable sea cucumber numbers and open fisheries	To achieve a population of sea cucumbers that can provide income from the fishery into the future

Step 5: Determine Trade-offs

Based on the consequence table above we can determine trade-offs for the alternatives considered in managing the sea cucumber fisheries in the Galápagos Marine Reserve. These trade-offs may include:

Alternative 1, no intervention, which presents immediate advantages in terms of no cost and ease of implementation. However, this approach comes with the trade-off of a negative impact on the sea cucumber population density and potentially low social acceptability, highlighting the need to balance short-term convenience with long-term ecological sustainability and stakeholder engagement.

Alternative 2, the development of a comprehensive research and monitoring program, offers promising benefits such as moderate cost with high feasibility and a potential increase in the sea cucumber population density. Despite these advantages, there are trade-offs to consider, including the requirement for effective communication to ensure social acceptability.

Alternative 3 involves the co-development of fishing regulations. While this approach presents a neutral impact on the sea cucumber population density and the potential for a positive impact on other species, it comes with challenges, such as moderate difficulty in implementation and enforcement, as well as potentially moderate social acceptability. These trade-offs underscore the complexity of regulatory measures and the importance of balancing ecological and social considerations.

Alternative 4 focuses on strengthening law enforcement and the use of technology. Although this option could positively impact the sea cucumber population density and other species, it entails a high cost of implementation and moderate social acceptability. Additionally, there is a moderate risk of unintended consequences, highlighting the need for careful planning and risk management.

Overall, the trade-offs between these alternatives involve considerations of cost, feasibility, potential impacts on other species, and social acceptability. Ultimately, a decision about which alternative to choose will depend on a careful evaluation of these trade-offs and the specific context of the Galápagos Marine Reserve.

Step 6: Implement Decision and Monitor

The last step of the SDM process for the sea cucumber fisheries management would be to make a decision based on the consequence table and the trade-offs identified. The decision should consider all the available information, including the objectives, the consequences of the different alternatives, and the trade-offs involved. In this case, the decision could involve selecting one of the alternatives presented in the consequence table, or a combination of them, that would maintain the sea cucumber density at a healthy population level while minimizing the trade-offs identified.

It is important to note that the decision should also consider the preferences and priorities of the stakeholders involved in the decision-making process. Involving stakeholders can help ensure that the decision is acceptable and that it will be effectively implemented. Therefore, the decision should be communicated clearly to all stakeholders involved, and the implementation of the chosen alternative(s) should be carefully monitored and evaluated to ensure that the objectives are being achieved and the trade-offs minimized. The interactive workbook (see Section 4) links strategies to objectives and their outcomes, which can be used together with other sources of information to revise management decisions.

Table 3. Consequences Table to Compare 4 Alternatives

Criteria	Alternative 1: No intervention	Alternative 2: Develop a comprehensive research and monitoring program	Alternative 3: Co-development of fishing regulations	Alternative 4: Strengthen law enforcement and use of technology
Potential impact on sea cucumber population density	Negative	Increase	Neutral	Increase
Potential impact on sea cucumber population density	Negative	Increase	Neutral	Increase
Feasibility	Easy to implement	High feasibility	Moderately difficult to implement and enforce	Moderate feasibility, dependent on financial resource availability, technological infrastructure upgrade, and regulatory hurdles
Potential impact on other species	No impact	Positive impact	Neutral	Positive impact[24]
Risk of unintended consequences	Low	Low	Low	Moderate

Lenfest team discussing structured decision-making with Galápagos National Park staff

Photo credit,
Jasper Yucailla

Section 4: Supporting Tools for the SDM Process

Tool #1: The Cost and Benefit Data Management Tool

Relevance

The Galápagos Protected Areas directorate maintains a commitment to develop and implement management programs to accomplish its objectives. These programs all require funding, but the directorate has reported that current funding is inadequate to achieve desired objectives[11]. Managers want to be able to collect and query data on the costs of activities and the benefits of their activities in relation to objectives. Such data could make clear the link between funds spent on management strategies and the conservation outcomes of those strategies. This information could then support future decisions about their operations.

Introduction to the Tool

We have developed a data management tool to help managers collect and query data on the costs and benefits of management. Here we introduce the tool, an interactive workbook in Microsoft Excel, and provide a high-level overview of how to use it in a case study of the local red spiny lobster fishery. The tool is designed to enable managers to track data on conservation strategies along with their corresponding costs and link them with indicators to gauge progress toward objectives.

It is important to note that the tool is not intended to prioritize strategies. Instead, it collects information and summarizes data, which provides managers with information they can later use for their own needs (e.g., to do a cost-efficiency analysis to assist them in the decision-making process.

To use the worksheet properly, macros must be enabled.

How the Tool is Organized

Each workbook is designed to support cost reporting for one conservation target. A target can be a species, a habitat, or an ecological system that is the focus of intervention[4]. We used the conservation of the red spiny lobster in the context of a marine protected area, but this tool can be applied to other conservation contexts. In the workbook, you can walk through data organization, data entry, and data summarization in separate sheets (see Figure 9, Part A, B, and C). The first two sheets (steps 1–2) will help set the context of the conservation issue (i.e., define the problem), link threats to management strategies, and define objectives while also measuring achievement toward them. The next three sheets (steps 3–5) are intended to collect specific information about the management strategies, indicators of objective achievement, and costs. The last sheet provides some example summary statistics that can be performed using the data collected in the previous sheets (step 6).

Steps to Use the Tool

Part A: Data Organization.

Part A will help you to set the context of the conservation target, link threats to management strategies, define objectives, and indicate how to measure achievement toward objectives. This step enables the data management structure to be set up so that it can support an understanding of progress toward objectives. We will do this in two steps: clarify situations and define strategies.

Step 1: Clarify Situations. First, we go to the "Situation" sheet. Here, we (a) state the main threat to the conservation target of interest, (b) break down this main threat into specific issues that contribute to it, and (c) identify the contributing factors that the managers can implement strategies to abate.

For example, the red spiny lobster is impacted by several environmental phenomena, such as global warming; human activities, such as unsustainable fisheries; and other threats. These could be due to contributing factors, such as excessive annual catch and lack of surveillance and enforcement of current fishing regulations (see Figure 10).

We also identify possible management strategies that could abate some of these contributing factors, such as devices to monitor the fishing boats, regulations on the fishing season, and other aspects of fishing activity.

Figure 10: "Situation" Sheet

Situation

Scope: Galapagos Marine Reserve
conservation target: Red spiny lobster

Main threat	Contributing factors	Strategies
Unsustainable local fishery	Excessive catch	Fishing calendar
	Lack of surveillance	AIS devices

Step 2: Define Strategies.

Next, we specify the logical steps of how the strategy is expected to lead to the intended conservation benefit (and thus achieve objectives). This provides a structure for identifying the costs that are incurred by each step of the intervention strategy. It also details the management objectives to be achieved by each step and provides indicators to measure progress toward these objectives.

On the "Strategy" sheet, we (a) break down each strategy (defined in the "Situation" sheet) into its intermediate steps, (b) relate a management objective to each intermediate step, (c) specify the concrete activities that will help reach each intermediate step, and (d) assign indicators, if any, to measure how well the management objectives are being accomplished through the corresponding activities. See Figure 11 for the example of the fishing calendar and the red spiny lobster and Figure 12 for the input of this information into the workbook.

Figure 9: Flowchart of the workbook

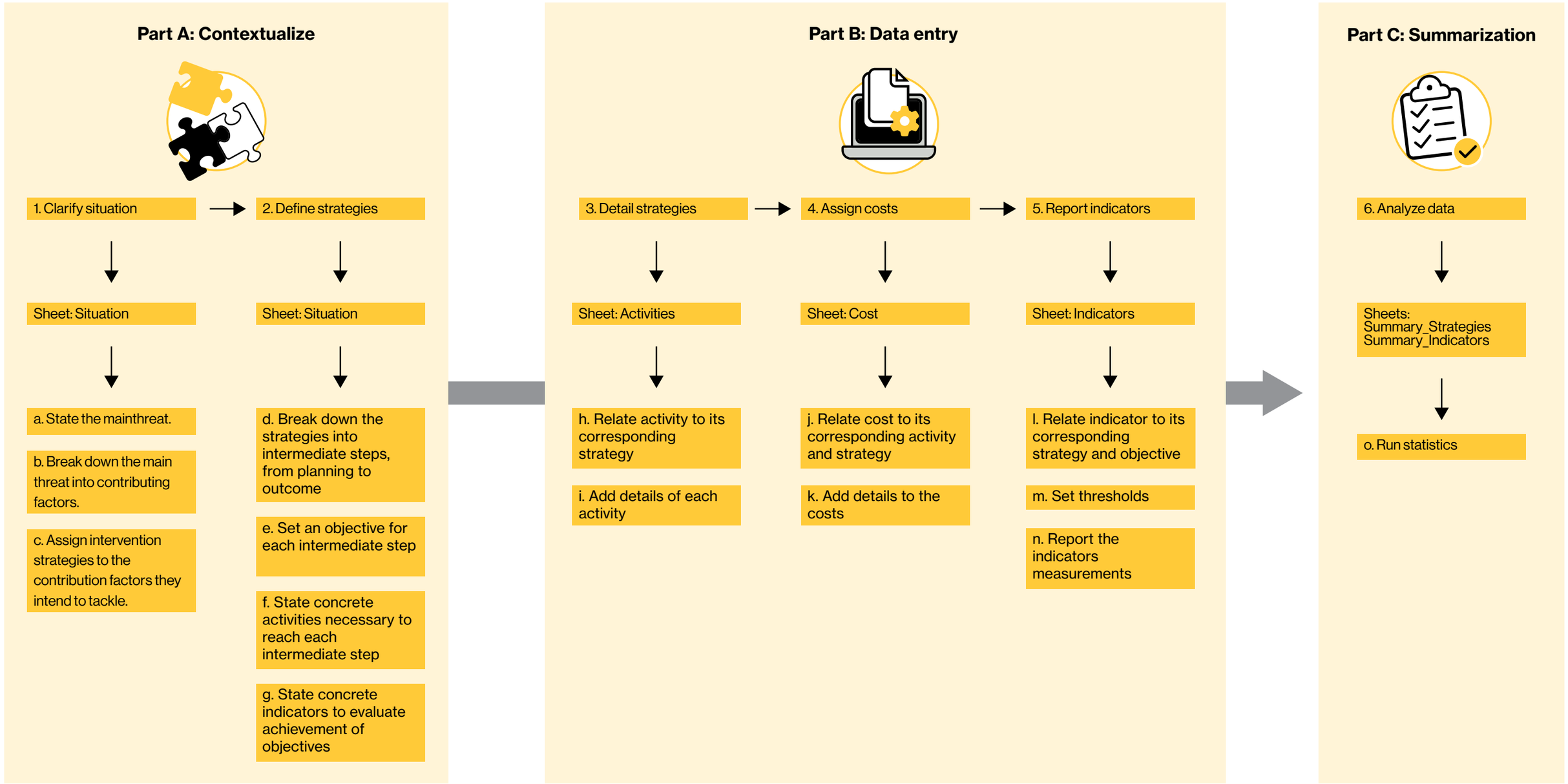


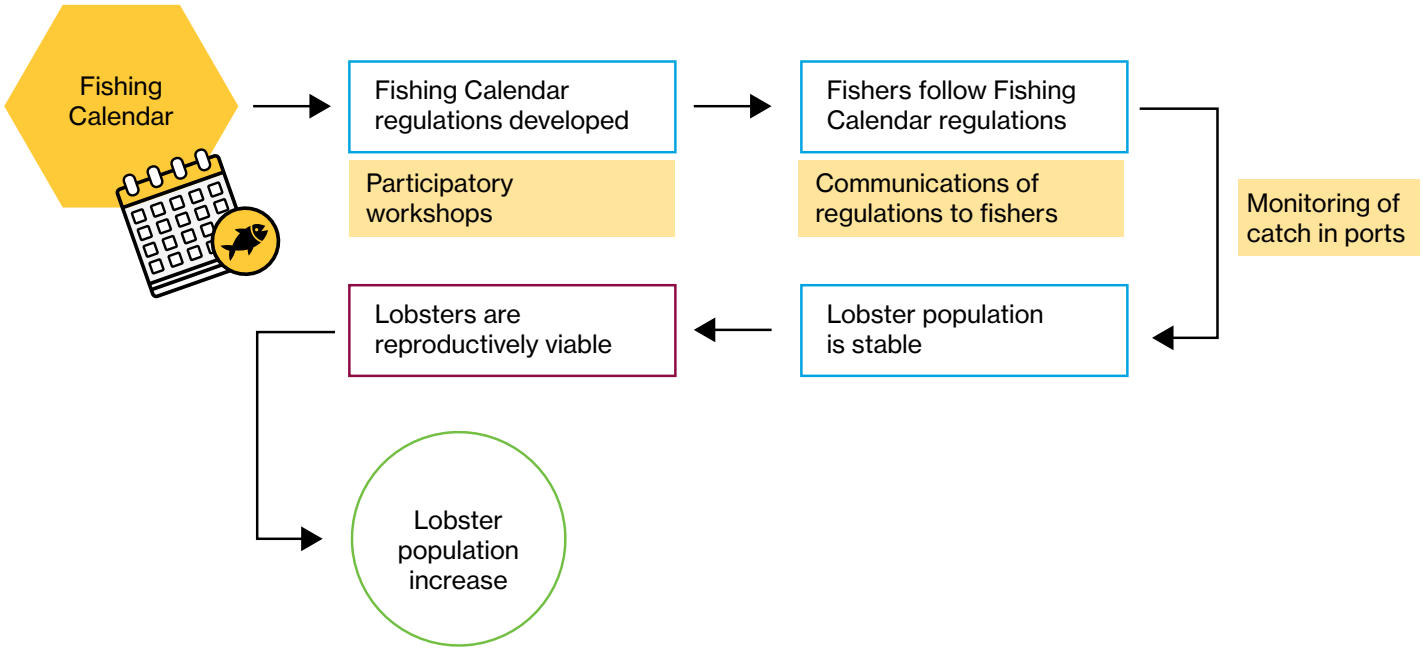
Figure 12: "Strategies" Sheet

Strategy	Intermediate results	Objectives	Activities	Indicators
Fishing calendar	Fishing calendar regulations developed compliance increases among lobster population stabilize/ recover	The fishing calendar is revised and updated every 5 years. Ensure fishers follow the regulations. State of lobsters populations is monitored.	Participatory workshops Monitoring of catch in ports Annual population monitoring	Mortality CPUE Reproductive potential
AIS devices	AIS Intermediate result 1 AIS Intermediate result 2	AIS Objective 1 AIS Objective 2	AIS Activity 1 AIS Activity 2	

Figure 13: "Activities" sheet

Ref. Strategy	Type	Activity/ Monitoring	Methodology	Actors	Context	Scale	Duration	Implementation progress
1. Fishing calendar	Activity	Participatory workshops	5 sessions	Fishing associations, park, directorate representatives	The first 5 sessions are for specific resources. The 6th is the socialization of the final document	Scale	1 month	Completed
2. Fishing calendar	Monitoring	Annual population monitoring	Methodology	Actors	Context	Scale	4 month	Planned
3. Fishing calendar	Monitoring	Monitoring of catch in ports	Indicators to measure: catch, catch per unit	Fishers, park authorities	Context	Scale	1 year	Planned
4. AIS devices	Activity	AIS Activity 1	Methodology	Actors	Context	Scale	1 year	On track

Figure 11: Case study: Fishing Calendar and the Red Spiny Lobster



Part B: Data Entry.

The second part of the tool contains three sheets for entering details of management strategies to organize cost information that is relative to strategy implementation and indicator details. We will do this in three steps: detail strategies, assign costs, and report indicators (see steps 3–5 in Figure 9). Remember (from step 2) that each strategy is composed of particular activities necessary to complete each intermediate step.

Each strategy can have indicators of achievement toward its particular objectives. Strategies can vary with time, new activities might be necessary to achieve the management goals, and new costs can be generated. To capture the dynamic nature of management processes, the workbook allows edits to existing data and continuous input of new available data at any time.

Step 3: Detail Strategies.

First, we input information regarding each activity in the "Activities" sheet. To do this, we (a) specify the strategy to which the activity corresponds and (b) add details of the activities to cost. Such details include the methodology of the activity and actors involved, as well as context, scale, and duration of the costed components.

Remember our context for the fishery of the red spiny lobster example (see Figure 11). Go to the "Activities" sheet and click the button "Add new Activity or Monitoring" (see Figure 13). This will prompt a user form that walks through the necessary data to input:

- Select the strategy to which the fishing calendar corresponds: "Fishing Calendar".
- Choose "Activity" because this is not intended to measure goal achievement (not an indicator).
- Select the activity and then describe relevant details about it.

- Repeat this process for the rest of the activities.
- Consider downloading the data as a CSV file for later analysis using the corresponding button.

Step 4: Assign Costs.

Next, go to the "Costs" sheet to pair the estimated or incurred expenditures with each activity. This will enable tracking investments into a strategy and comparison of costs across different strategies. In this sheet, we (a) link each cost to an intervention strategy and corresponding specific activity and (b) add details to each expenditure, such as category, type, currency, duration, and date (see Figure 14).

We click on the button "Add new", specify the strategy and the activity, then identify the cost component. We will start with staff time to make the purchase:

- Category refers to broad types of costs, with choices for labor, capital assets and equipment, overhead, and consumables.
- The type of costs refers to whether the cost changes with the scale of the project (variable), such as fuel, or not variable (fixed), such as office expenses.
- Then, add the cost currency, duration, and date.
- Use the last box to add any important detail.
- Do the same for the other costs.
- One can also download the data as a CSV file for later analysis.

Step 5: Report Indicators.

Finally, we go to the "Indicators" sheet. Remember that we want to pair costs with the outcomes (benefits) of different intervention strategies to support future decisions. The "Indicators" sheet relates monitoring results to the corresponding management objective, whose achievement they are intended to measure.

In this sheet, we (a) link the indicators with the corresponding strategy and the particular objective they are intended to evaluate, (b) specify the thresholds used to make decisions, and (c) report the measurement and details of the measurement.

Going back to our case study of the red spiny lobster fishery, we need one or several indicators to measure the effectiveness of a fishing calendar in maintaining a sustainable lobster population. Example indicators are mortality, reproductive potential, and catch per unit effort (CPUE) (see Figure 15).

Part C: Summarization.

In this last part, we provide a few broad example summary statistics. Keep in mind that the data collected in this workbook can be downloaded (steps 3–5) and managers should perform analyses that fit their particular needs to support future management decisions. Also remember that the workbook allows the user to change existing data and add new information at any moment, so any change can be updated.

Step 6: Analyze Data.

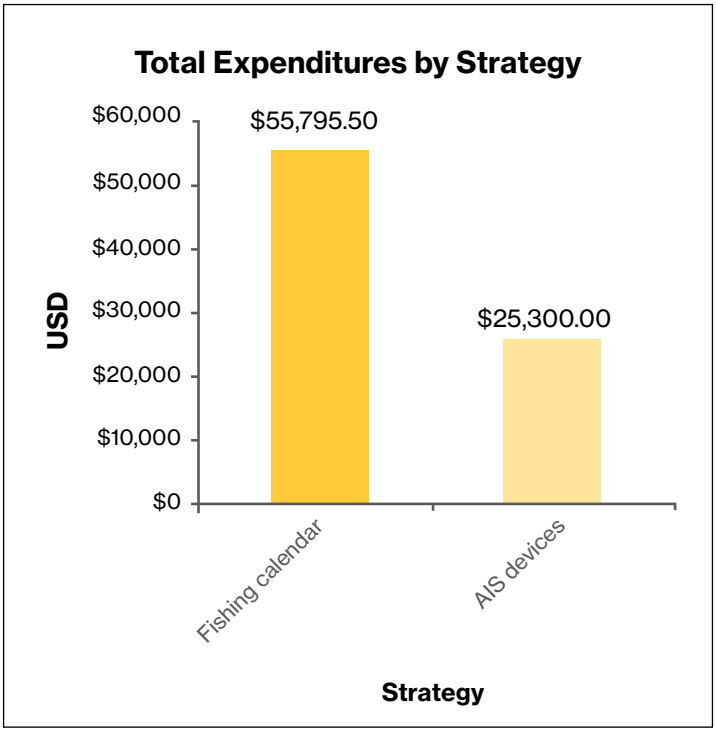
The “Summary_Strategies” sheet can generate some general example plots about total expenditures by strategies and implementation progress. The “Summary_Indicators” sheet can calculate example plots about management objective achievement. Please note these are not the only analyses that can be done with the data collected in the workbook. These data can be used for a more tailored cost-efficiency analysis to help managers in their decision-making process.

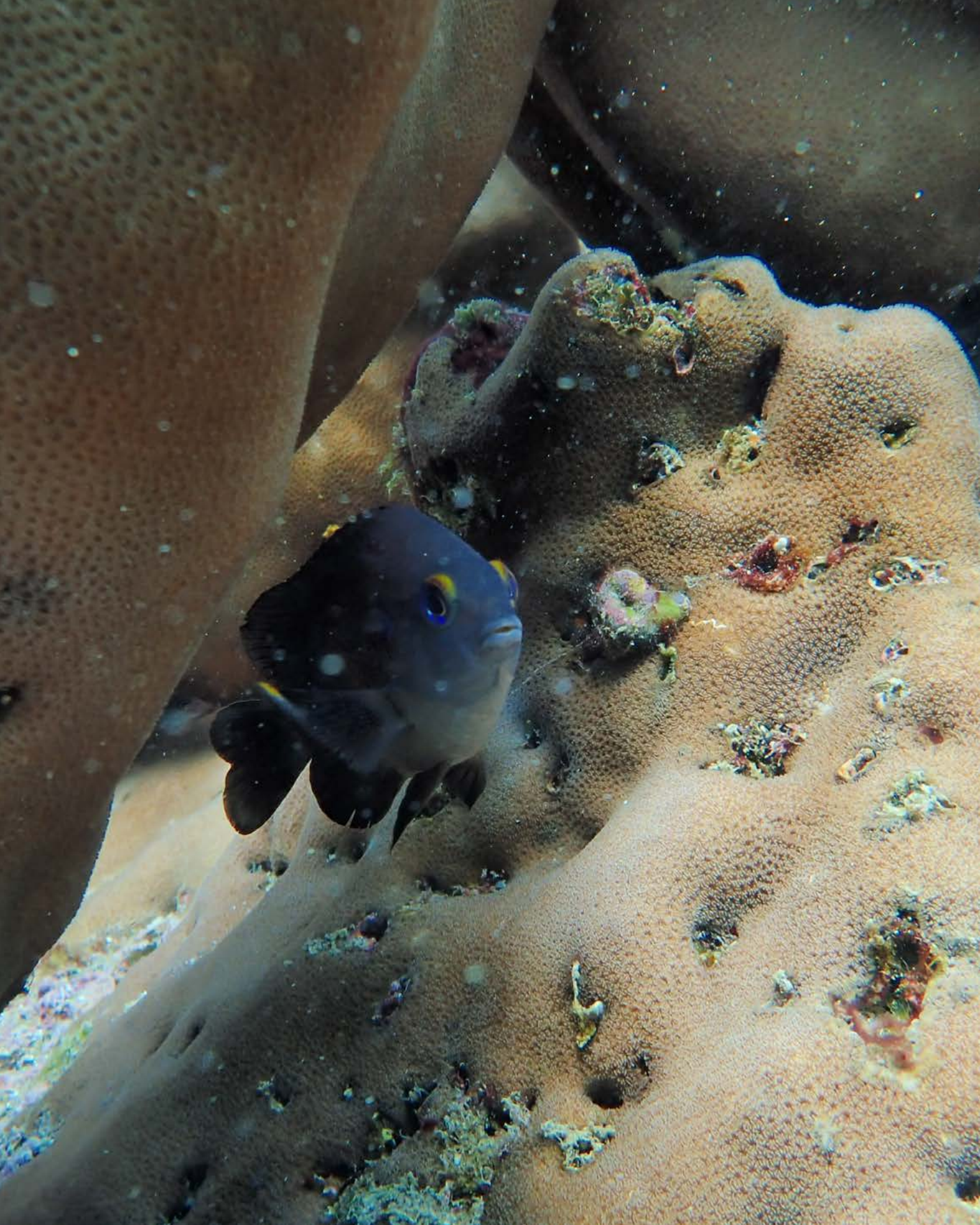
We can see how the workbook shows the total expenditures by different strategies (see Figure 16).

Figure 16: “Summary_Strategies” Sheet

Strategy	Fishing calendar	AIS devices
Total expenditures	$55,795.50	$25,300.00

Last updated: 16-Feb-2023





Appendix 1

Worksheet used during the “Structured Decision Making Framework for the Galápagos Marine Reserve”

Workshop 1 (WS1)		
Group:		
Topics where there is a problem to resolve	**What is the problem?**	**Is a decision required to solve the problem?**
List applicable topics or cases	Write the problem	Yes or no

Figure 14: "Costs" Sheet

Ref. Strategy	Activity/ Monitoring	Component	Category	Type	Cost	Units	Duration	Start date (mm/dd/yyyy)	Description/ notes
1. Fishing calendar	Participatory workshops	Planning	Labor	Fixed	100	USD	3 days	8/ 18/ 2021	Series of 3 planning in meetings on these dates 08/18, 09/30, 03/01
2. Fishing calendar	Participatory workshops	Cleaning of room	Labor	Fixed	100	USD	1 days	3/21/2022	N/A
3. Fishing calendar	Participatory workshops	Leader of workshop	Labor	Fixed	5488	USD	1 week	7/14/2022	External funds. Total for 6 workshop sessions.
4. Fishing calendar	Participatory workshops	Transportation workshop leader	Consumable	Variable	990	USD	2 days	3/21/ 2022	Costs of each entry to the Galapagos for the total of 3 workshops regarding lobster (330 each entry)

Figure 15: "Indicators" Sheet

Ref. Strategy	Activity/ Monitoring	Component	Date	Measurement	Threshold	Units	Positive outcome	Target outcome
1. Mortality	Fishing calendar	Monitor lobsters populations state	1/1/2022	0.9	1	-	Yes	Measurement < threshold
2. Reproductive potential	Fishing calendar	Monitor lobsters populations state	1/1/2022	0.53	0.4	-	Yes	Measurement > threshold
3. CPUE	Fishing calendar	Monitor lobsters populations state	1/1/2022	2	1.5	-	No	Measurement < threshold

Workshop: Structured Decision Making Framework for the Galápagos Marine Reserve

Workshop 2 (WS2)						How important is the decision to be made?				How urgent is the decision to be made?			
Group:													
						Rate from 1 to 5				**Rate from 1 to 5**			
Topics from WS1 that require a decision	Is there more than one alternative solution?	Is there more than one alternative solution?	Are data available to evaluate alternatives?	Are there risks associated with the decision?	Can the decision lead to unexpected results	Environment aspect	Social aspect	Economic aspect	Political aspect	Environment aspect	Social aspect	Economic aspect	Political aspect
List applicable topics or cases	Yes = 1 No = 0	Yes = 1 No = 0	Yes = 1 No = 0	Yes = 1 No = 0	Yes = 1 No = 0								

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