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# STAKEHOLDER PREFERENCES FOR REGIONAL MANAGEMENT OBJECTIVES: A CASE OF THE FLYINGFISH FISHERY OF BARBADOS AND TOBAGO

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## Abstract

This study is an application of a pairwise comparison technique to determine weighted rankings of objectives for regional management of the Flyingfish fishery. The results of this research is intended to guide policies and programs to further develop the social and economic potential of the Flyingfish fishery while maintaining ecological sustainability.

Results reveal a hierarchy of management objectives ranked in order of preference. Ranking order varies slightly between respondents with different nationalities, occupations, and boat types.

In addition to the hierarchy of management objectives, findings demonstrate the following: respondents overwhelmingly supported sustaining the Flyingfish resource as the foundational management objective; respondents' preferred management approach is development of fishery, through investment (facilities for processing and storage), and operational support (monitoring, enforcement, marketing); respondents understood the fishery at the ecosystem-scale, supporting the ecosystem approach to fisheries management; and respondents conceived of the fishery as part of an interconnected complex system with feedback loops; modelling of the system for the purposes of planning and evaluating management should consist of a complex system rather than a linear hierarchy.

## 1. INTRODUCTION

Due to the dynamic and interconnected nature of social and ecological systems, managing resources in accordance with the ecosystem approach (see Box 1) requires a flexible system of governance which can adapt to changing priorities and emerging issues. The ecosystem approach also requires consideration of the resource in relation to both social and ecological factors, even if their influence may not appear to be as dramatic as fish harvesting.

In accordance with the ecosystem approach, adaptive management (Holling 1978) is a strategy grounded in an acceptance of the complex and uncertain nature of interactions between humans and ecosystems. Instead of firm, top-down management policies and activities, managing adaptively involves formulating flexible and experimental policy and programs to test managers' understanding of the ecosystem and to increase awareness of the key processes and thresholds of the system. The goal of adaptive management is to gain understanding of the dynamics, feedbacks and thresholds of the system, and this information can help managers understand how to promote long-term resilience of the system and identify key thresholds before they are reached (Berkes *et al.* 2003; Plummer and Armitage 2007).

Ongoing stakeholder involvement in consultation, collaborative governance and co-management activities are key components of adaptive management. Finally, this adaptive approach is particularly relevant for fisheries, which are chronically characterized by uncertainty and complexity.

### 1.1 CLME Project as a Model for the Ecosystem Approach to Fisheries

The Caribbean Large Marine Ecosystem (CLME) project is a four year Global Environment Fund (GEF) project which is intended to facilitate collaborative ecosystem-scale sustainable management of the shared living marine resources of the region through an integrated or ecosystem-management approach (CRFM 2010; UNDP 2010). Specific objectives of the project include:

- Identifying, analyzing and agreeing upon major issues, root causes and actions required for sustainable regional fisheries management

#### **Box 1: The Ecosystem Approach**

The ecosystem approach is a management theory which accepts that humans are a fundamental component of ecosystems and accordingly promotes both conservation and utilization of resources. It involves adaptive techniques to manage the complex and dynamic nature of ecosystems. These techniques do not preclude existing conservation and management approaches, but incorporates them into a holistic system with feedback loops to evaluate their effectiveness and encourage innovation and adaptation (Wang 2004; Fanning *et al.* 2007).

The key principles of the ecosystem approach are to sustainably manage human use of resources in a way that conserves species and their habitats, including species that are not economically valuable; to base management decisions on sound science; to consider the long-term scope of resources and therefore ensure equity between present and future generations; to consider all scales in management; and to manage in a dynamic, adaptive way (Wang 2004; Fanning *et al.* 2007). The ultimate goal of the ecosystem approach, however, is to encourage resilience- the ability of the system to adapt to change and absorb disturbance. Resilience is key to the long-term sustainability of the ecosystem (Gunderson and Holling 2002; Folke *et al.* 2005).

- Improving the shared knowledge base around sustainable use and management of transboundary fishery resources
- Implementing legal, policy and institutional reforms to achieve sustainable fisheries management
- Developing an institutional and procedural approach to regional monitoring, evaluation and reporting (UNDP 2010).

Specific project outputs include:

- A Transboundary Diagnostic Analysis (TDA) to develop fishery reforms, conservation measures, and pollution control in relation to transboundary marine resources within the region
- A Strategic Action Plan (SAP) - shared vision for the CLME will be developed, required policy interventions, reforms and investments agreed
- A regional governance framework for the CLME
- Improved linkages between the private sector, advisory bodies and decision-making bodies
- A monitoring and information network
- Detailed demonstration projects on Spiny Lobster, reef fish, and marine biodiversity, and focussed case studies on large pelagics, reef fish, shrimp and groundfish, and Flyingfish (UNDP 2010)

CRFM is responsible for implementing the Flyingfish and pelagic fishery case studies under the CLME project (Haughton 2010). The proceedings of the LPWG and SCPWG during the Annual Scientific Meetings that fall within the study period and in particular the results from the joint Flyingfish-Dolphinfish assessment described in this document are intended to contribute to the completion of these case studies as well as the continued development of the CLME project.

## **1.2 Need for innovative assessment tools beyond biological models**

Fanning *et al.* (2007) suggest that developing data-dependent and science-heavy models is not an effective use of time and resources because Caribbean governments and fisheries departments currently lack the capacity to respond to and effectively utilize this information; instead, a first step to an effective regional governance framework for the Flyingfish fishery is to develop linkages between multi-level actors within the region and developing a management framework in the form of a shared vision.

## **1.3 Need for stakeholder involvement and collaboration**

Fisheries are open access, shared resources which are critical for human livelihoods and food security. As a result of these social and ecological interconnections, an enormous amount of literature and experimentation has been devoted to the concepts of co-management, consultation and collaborative management involving stakeholders. However, many of these attempts to involve or collaborate with stakeholders has evolved as a response to conflict between resource users, concerns about declining availability of resources, or situations of critical resource scarcity. Accordingly, less scholarship and practical experience has been devoted to resource harvesting scenarios which appear to be sustainable and which have not yet reached a state of crisis or concern (Pomeroy and Rivera-Guieb 2006).

Involvement of key stakeholders at an earlier stage in the resource cycle can generate functional partnerships between management bodies and resource users before conflicts or crises emerge. Establishing a management framework with goals and objectives at an earlier stage means that the resource can be more effectively monitored and if a problem emerges, the necessary trust, partnerships and institutional capacity already exists to respond to it effectively. This is particularly true for fisheries management in the Caribbean, where monitoring and management capacity remains very limited.

## **1.4 Project Context**

If fisheries are understood to be complex adaptive social and ecological systems, then it is essential to take a holistic approach in any attempts to understand them. Historically, fisheries models or assessment tools focussed only on narrow biological criteria like catches of a single species, or economic criteria like the effort expended to catch a certain weight of fish. Aside from being an unreliable and potentially misleading method of assessing fishery health, it also excludes the full range of values that are associated with a fishery. This is particularly true for multi-species fisheries which have a diverse range of users and where the ecological effects of fisheries are complex and difficult to determine. If policy and management is guided by narrow criteria like catch per unit of effort, this decision-making framework will be ineffective at evaluating the true health of fishery according to multiple criteria, and ineffective in supporting projects and decisions which optimize these multiple criteria. These criteria are also ineffective at incorporating observations and expertise of the front-line resource users in fishery assessment, because their knowledge of the resource is far more sophisticated than tracking catches and numbers of trips and cannot be effectively incorporated into such narrow models.

In an effort to respond to the limitations of traditional fishery assessment, this project is intended to demonstrate and test an innovative approach to evaluation of the key social and ecological values of a multi-user regional fishery. The alternative tool being used for assessment is an adaptation of Multiple Criteria Analysis (MCA) technique. This study represents the first phase of the assessment, where a list of management objectives is compiled from existing reports and management plans, and these objectives are then evaluated and explicitly ranked by a sample of stakeholders. In the second phase of the study, a fellow intern will use these ranked objectives as weights which can be multiplied by the score for various indicators of performance on the objectives to produce a final assessment score indicating the state of the fishery. Or more specifically, this final score will indicate how well the fishery is performing according to the selected management objectives and their relative importance. More information on the MCA method is below, followed by a description of the process and progress of this first phase of the project.

## **2. METHODS**

Multiple Criteria Analysis (MCA) is a dynamic methodology for representing management objectives and how well they are being met over time. Broadly, MCA is used to assist in decision-making. MCA is not a conventional static model with data and science-heavy outputs which are difficult for policy makers and government staff to interpret and implement into management; instead, it is a tool for assessing the state of a goal with multiple objectives or for assessing decision options with multiple criteria.

It is most commonly used to decide between specific, independent decision options, but can also be standardized as a decision tree or framework to be used at multiple sites or to assist in decision-making for very specific cases. An example of a standardized multi criteria decision framework is evaluating the site for an aquaculture project (Halide *et al.* 2009), and an example of a case-specific application of MCA is the comparison of four specific management options for limiting long-liners in the Hawaii pelagic fishery (Leung *et al.* 1998).

### **2.1 MCA as an Assessment Framework**

In addition to assisting in the analysis of specific decision options, MCA can also be used as a framework for “mapping” management objectives in a hierarchy which indicates the relative importance of each objective as well as how objectives and criteria for measuring objectives relate to each other. This tool can be understood as an “assessment framework” rather than a decision tree or decision hierarchy because it summarizes how well multiple objectives are being met rather than the suitability of decision options.



In a fisheries context, an assessment framework could be used very effectively to provide a snapshot of the state of the resource in consideration of multiple objectives.

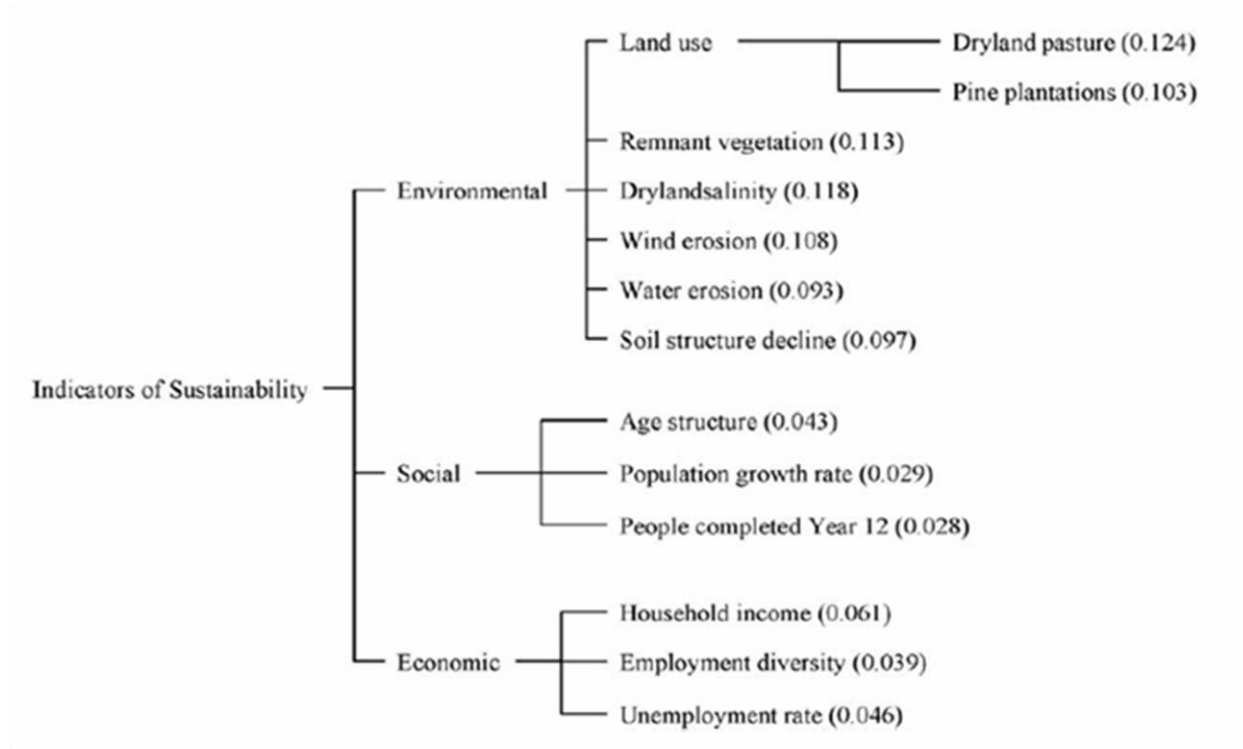


Figure 1: Weights applied to performance of indicators to demonstrate how criteria related to social, economic and environmental sustainability criteria are being met. From Graymore et al. (2009).

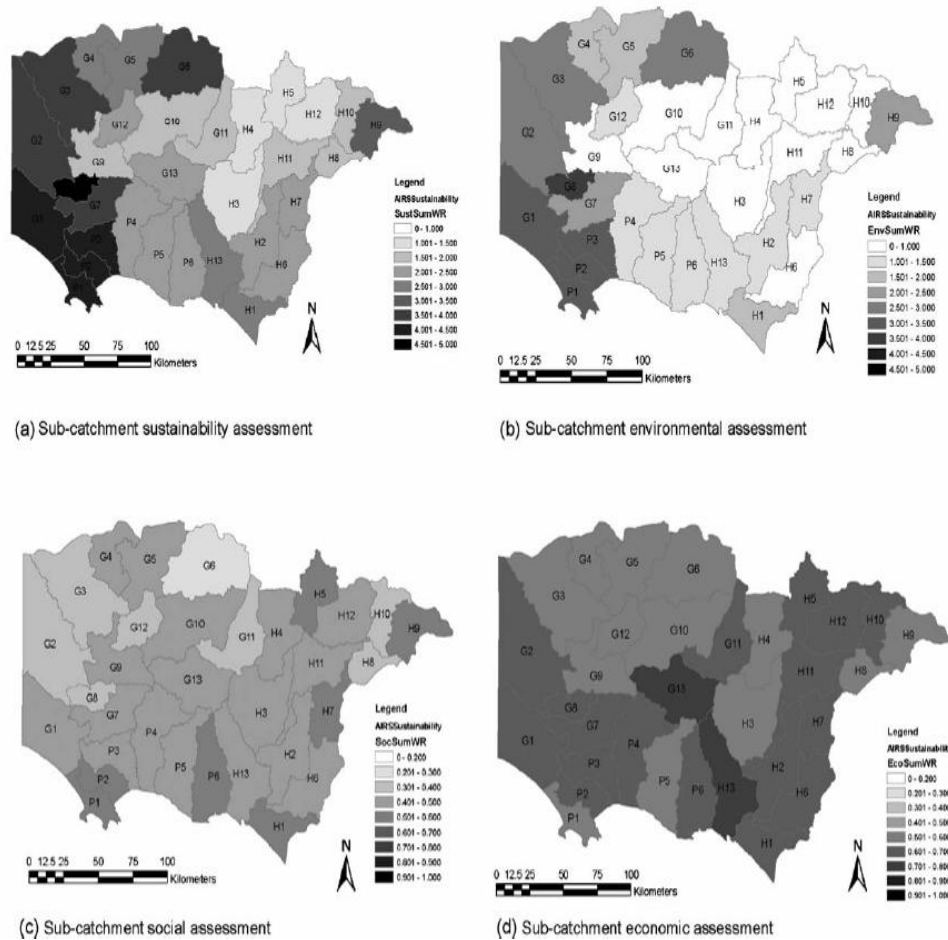


Figure 2: A visual index of a) overall sustainability, b) environmental sustainability, c) social sustainability, and d) economic sustainability, with a gradient ranging from 0 (white) indicating low sustainability to 9 (black) indicating high sustainability. From Graymore *et al.* (2009)

For example, Graymore *et al.* (2009) used an MCA assessment framework to map the degree of social, environmental and economic sustainability in river basins within a specific region in Victoria, Australia. In addition to numerical representation of the degree of sustainability (see Figure 1) the researchers visually mapped the data (shading each region on a gradient according to their degree of sustainability, see Figure 2). The numerical assessment of sustainability provides an explicit, quantifiable evaluation of the degree of sustainability, and the visual maps ensure that decision-makers can quickly and easily identify where to focus attention how different criteria interact (for example, if economic sustainability is high in areas where environmental sustainability is low).

In a similar way, MCA can be applied in a fisheries context to provide a snapshot assessment of the state of the fishery in relation to multiple objectives (example shown in Figure 3). The specific stages in this assessment-style application of MCA are described below. The assessment framework application of MCA can be a very powerful tool for assessing the degree to which highly subjective and complex management goals like sustainability are being met, which are otherwise very difficult to evaluate. MCA

is a broadly interpreted methodology with a number of specific applications. However note that use of MCA as an assessment tool is a somewhat innovative application of the methodology, because it is more conventionally used to inform specific decision options rather than as an assessment framework (Anandale 2011). Note that if a decision-making MCA tool is needed, an assessment framework containing objectives and criteria can easily be adapted to evaluate different decision options.

## 2.2 Stages in Generating an Assessment Framework Using MCA

1. Identify objectives that are key to satisfying the goal; identify criteria to satisfy the objectives; and identify indicators to illustrate performance of each criteria in relation to objectives
2. Organize the objectives, criteria and indicators into an assessment framework or hierarchy (Figure 3 shows an example from Mardle *et al.* (2004))
3. Determine the weighting (relative importance) of each objective and/or criteria in relation to the overall goal
4. Score performance of indicators
5. Multiply performance of indicators on each criteria or objective by the weight of the importance of that criteria or objective
6. Represent these final scores in the hierarchy to demonstrate how well each objective and/or criteria are performing in relation to the goal.

### Guide to Terms Used

**Objective-** general and over-arching goal that is being pursued by management

**Criteria-** measures the degree to which the management objective is being met

**Indicator-** an explicit measurement of how well criteria are being satisfied; dependent on available data

### 2.2.1 Development of objective hierarchy

General management objectives were drawn from the Draft Sub-Regional Management Plan and broad biological and socio-economic objectives were drawn from a “vision statement” provided in this management plan (see Figure 4). After internal discussion, it was decided that a third objective should be added representing the Ecosystem Approach to fisheries management. Incorporation of the Ecosystem Approach in the management of Flyingfish and other species in the region is a core priority of the CLMA project. As a result, an ecological objective related to ecosystem-scale considerations was also incorporated. This objective was specifically from the First CRFM/CLME Large Pelagic Case Study Meeting, but is not specific to large pelagics.

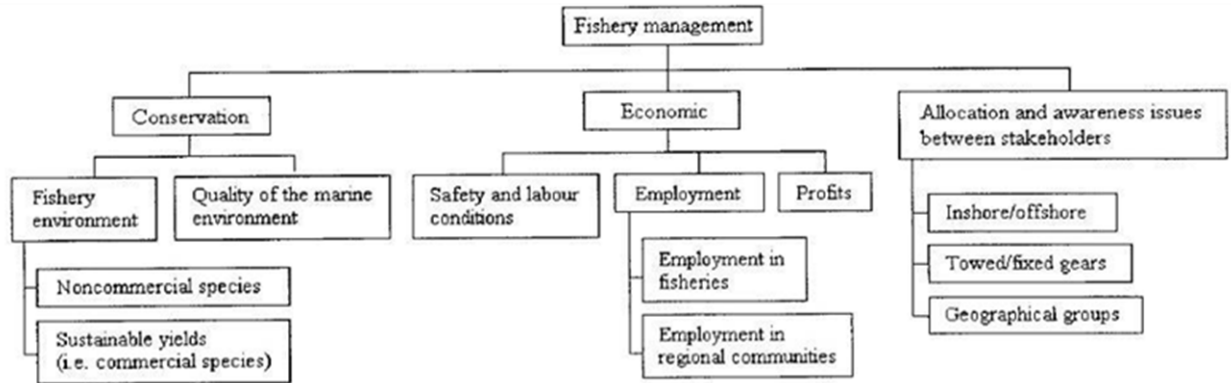


Figure 3: Example of a hierarchy from Mardle et al. 2004 of fisheries management objectives and criteria organized into an assessment framework, also called a “decision tree” in the literature because many applications of MCA are related to decision making.

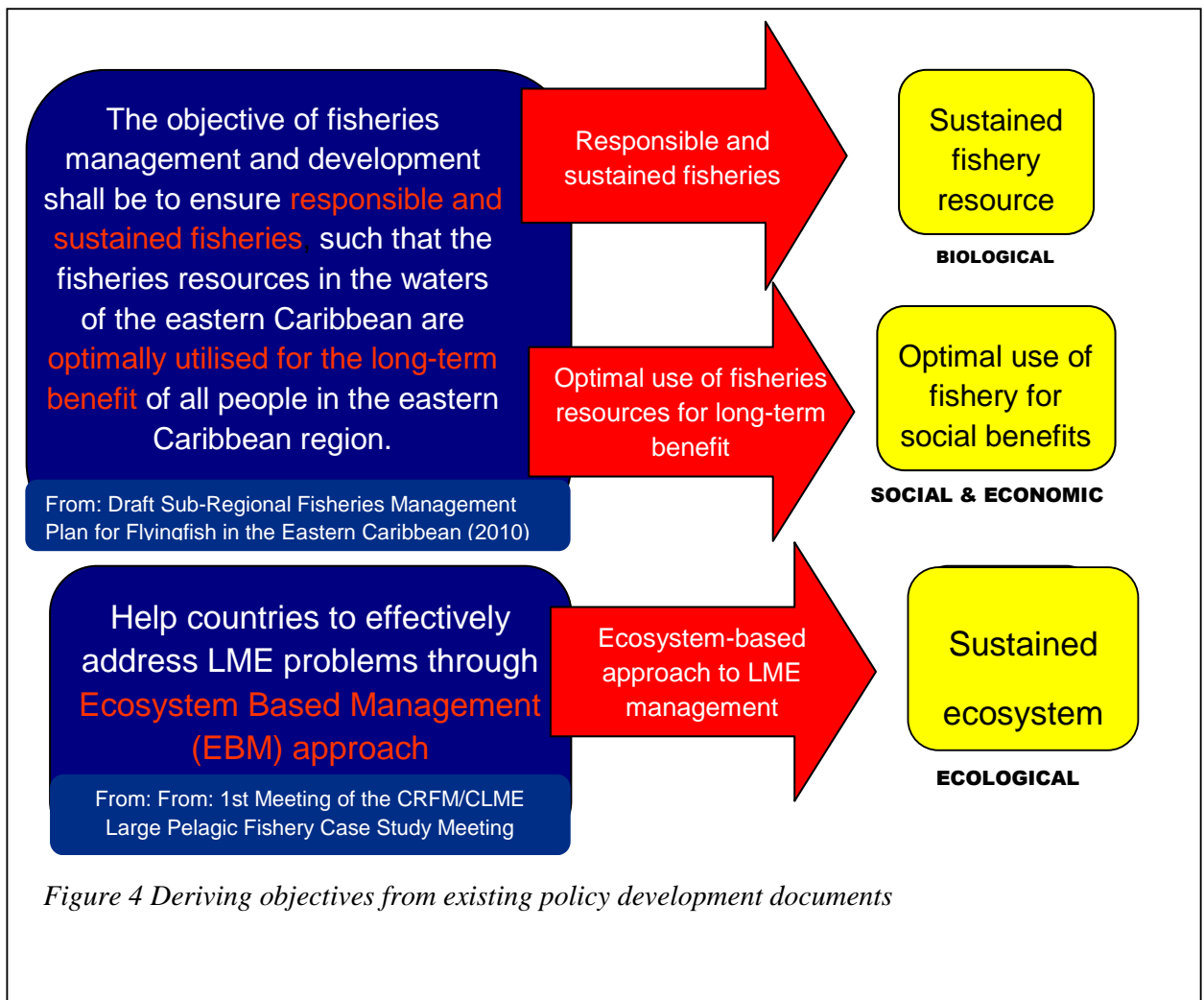


Figure 4 Deriving objectives from existing policy development documents

Once broad objectives were established, we conducted a review of existing reports and grey literature to identify more specific criteria and operational objectives to inform the performance of the general objectives. Reviewed documents included Draft Fisheries Management Plans from Barbados, Grenada and St. Lucia, Country Reports provided in the CRFM scientific meeting newsletters, meeting reports from the WECAFC Ad-Hoc Working Group, as well as contributions from the literature including FAO (1999) and Shin *et al.* (2010). Following an internal review process, operational objectives and associated criteria (which can be combined with indicator data during assessment) were developed.

*Table 1: Description of objectives and assessment criteria*

	Operational Objective	Description	Assessment Criteria	Description
Sustained fishery resource-Biological	Sustained resource	Ensuring that there are Flyingfish available for future generations  Preventing overfishing to maintain a healthy stock	Status of the resource	State of the Flyingfish resource represented by changes in known biomass over time
	Accurate information	Ensuring that an effective data collection system is in place to provide accurate information and knowledge about the state of the fishery	Effectiveness and accuracy of monitoring	Scope and reliability of monitoring program and effectiveness in informing management decisions.
	Effective management	Ensuring that there is an effective system for management and enforcement to management as needed  Effective management is adaptive, responsive to changing information about the fishery, and involves stakeholders in decision-making	Management capacity	Degree of effective, informed and precautionary management.  Ability to enforce management decisions.  Ability to collaborate effectively with stakeholders and other countries and organizations both vertically and horizontally
Optimal use of fishery for long-term benefit-Social and Ecological	High profits	Optimal economic benefits for all involved in the fishery	Income from fishing	Value of economic profits from fishing
	Affordable food source	Ensuring that Flyingfish remains an affordable and available source of food for the future	State of food security	Affordability and availability of Flyingfish for local consumption
	Fair access to	Fair and equitable access to	Equity in	Degree of fair and

	fishing	fishing resources Minimal competition from other resource sectors	access to fishing	equitable access to fishing resources; degree of competition from other resource sectors; equity of resource-sharing between countries
	Successful processing and export market	Developed post-harvest production and export of Flyingfish	Success of post-harvest market	Value of post-harvest production and export
Sustained ecosystem health- Ecological	Healthy habitat	Healthy habitat with minimal degradation and minimal impact from pollution or other negative effects	Habitat health	Degree of habitat degradation from pollutants or other negative effects
	Balanced ecosystem (balanced trophic levels)	Ecosystem with balance between predator and prey species	Balance in ecosystem	Degree of balance in feeding relationships between predator and prey species
	Resilience to environmental change	Ecosystem that can withstand the effects of climate change, extreme weather events and other environmental changes	Resilience to environmental change	Ability of ecosystem to withstand environmental changes including climate change or extreme weather events

### 2.3 Description of Field Work

Field work was conducted in Barbados and Tobago in May 2011. Field days included a total of four and a half days in Barbados and three days in Tobago. Local fisheries department contacts provided transportation and were relied upon for verifying the most appropriate sites to visit. Barbados staff was able to make introductions with fishermen at the Bridgetown landing site on the first day of field work, and Tobago staff was able to accompany the researcher and make introductions for all three field days.

#### 2.3.1 Sampling location

Loose guidelines for sampling locations were prepared based on available written information about the Flyingfish fishery. In Barbados, we sought to sample fishers and processors from a mix of landing sites on both the windward and leeward coasts, as well as include both day boats and ice boats. In Tobago, we sought to sample the most significant sites for Flyingfish, Pigeon Point, Buccoo, and Scarborough, well as both day boats and ice boats.

Results provide a snapshot of stakeholder opinions that can be used to assist policy and decision-making, but are not a substitute for consultation or further studies in the case of controversial or high risk decisions. Due to the small-scale, experimental nature of the study, we pursued a minimum sample size of 32. See Table 1 for a break-down of the number and type of respondents by location.

Table 2: Respondents organized by type, country, and landing site

	Landing Site	Total Fishers	Day Boat	Ice Boat	Processors	Fisheries Staff	Fisherfolk Organizations
Barbados	Bridgetown	7	0	7	5	2	0
	Oistins	3	3	0	1	0	0
	Consett Bay	4	4	0	0	0	0
	Weston	2	2	0	0	0	0
	Total	16	9	7	6	2	1
Tobago	Scarborough	2	0	2	2	1	0
	Buccoo	3	3	0	0	0	0
	Pigeon Point	5	5	0	0	0	0
	Total	10	8	2	2	1	0

### 2.3.2 Field work procedure

Off-duty fishers were approached on the dock, in the fisheries complex or on their own boats. Following introductions, the researcher then explained that the study was part of a regional initiative to develop policy and management objectives for the Flyingfish fishery. It was explained that the first step in this process was to speak to stakeholders including fishers and processors, and determine their management preferences as well as any issues or concerns that they may have. If the individual agreed to participate, it was explained that the study involved sorting cards in order according to their opinion, and they were invited to discuss the sorting of the cards either during the sorting process or after they were satisfied with their sorting. The researcher then displayed the cards one-by-one while explaining what was meant on the card. While variance in the meaning of terms is an issue in any cross-cultural or international field work, effort was made to ensure that the language was as clear, direct and jargon-free as possible. The researcher listened carefully and adopted local terms to explain certain concepts where these were observed to be more locally prevalent. For example Barbadian fishers refer to their homemade FAD as a “screeler.”

In some cases both fishers and processors were hesitant to comment on a particular objective because they saw it as outside their realm of expertise. For example a few fishers said they could not comment on the objective relating to processing because they weren’t directly involved in that activity. The researcher explained that since the project is looking at the fishery as a whole, connected system, while catching fish may be their main activity, they would not catch those fish without a processor to sell to, and that processor would not buy that fish if there was no market, and so on. Because they eventually profit from the sale of fish they are directly connected to markets and processing and are very much entitled to comment on them. Following this clarification these respondents felt comfortable discussing all of the management objectives.

### 2.3.3 Description of pairwise comparison method

A modified pairwise comparison technique was utilized to enter and analyze the ordinal data. In a conventional pairwise comparison, respondents are asked to compare two variables (such as decision options, criteria, or management objectives in the case of this study) and indicate which they prefer or believe to be most important. Using this method, each option is systematically compared against every other option.

In this study, preliminary field testing of the pairwise comparison method revealed that the amount of time and respondent attention required to complete the entire analysis was prohibitive. For example, each session would require approximately an hour of respondent time, which was not possible with only 8 field days. Additionally, because respondents were approached while coming in after a day working at sea (or in some cases, after two weeks at sea), a focussed, hour-long survey would be too demanding of their time and attention.

Due to these limitations, an alternative technique was used to acquire the pairwise comparison sorts. Simos (1990, as described in Ondrus and Pigneur 2006) proposed a method using a pack of cards to indirectly solicit weights for variables. In this technique, respondents are asked to arrange the cards according to their importance from 1 to  $n$ . To determine the degrees of difference in importance between each variable, Simos suggested that respondents can insert blank cards to indicate greater and smaller gaps in the weights. This technique would provide weights similar to the AHP, where variables are ranked in order of importance but differences in importance within this ordinal ranking are also noted. However, this technique again requires more respondent time. Ondrus and Pigneur (2006) note that because respondents are asked to first sort the cards ordinally (in order from most to least important), this data can then be converted to numerical weight values to represent the relative importance of each variable.

We chose to then convert this ordinal data into pairwise comparison tables. That is, if a respondent sorted card A as more important than card B, card A was recorded as being more important in the pairwise comparison. Note that this assumes that by positioning a card in a certain level, the respondent believed this card to be more important than all those below it, less important than all those above it, and of equal importance to those in the same level.

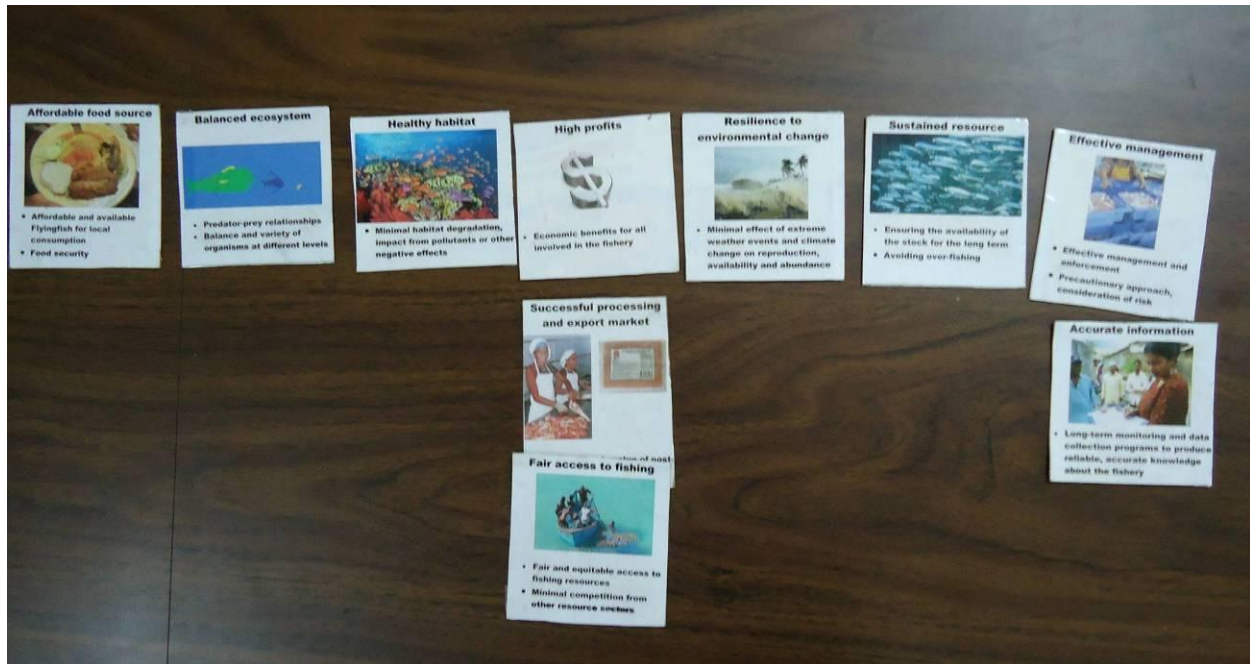


Figure 5: A sample sort



2.3.3.1 Data recording

The order in which respondents sorted the cards and their comments during the sort were recorded on a standardized data form. For example, if a respondent mentioned food safety issues in relation to why they sorted “Successful processing and export market” highly, their comments about food safety were associated with the card on the data form. This facilitated coding of the qualitative data provided by the comments. In cases where respondents discussed topics that did not relate to a specific card or the sorting process, this information was recorded separately.

2.3.3.2 Data entry

Each respondent was assigned a code indicating their respondent number (from 1-37). Data was entered into a standardized, colour-coded form in an Excel spreadsheet. The order of the cards was entered in binary form using a pairwise comparison technique. Beginning with the row of the objective that they sorted as #1, a 1 was entered in every cell in that row. Next, a 0 was entered in every column for that objective. In the example below, “Information and monitoring” was sorted as #1, so a 1 was entered into every cell in the row for that objective (highlighted in yellow, see Figure 6). Next, a 0 was entered into every cell in the “Information and monitoring” column for that objective. For the objective sorted as #2, the same process was followed for the rows and columns except that where numbers were entered to represent the #1 objective (see cells outlined in bold in Figure 7). This process was followed for all ten objectives (see completed data form in Figure 8).

1											
2	1: H-W1	Sustainable resource	Information and monitoring	Management	Profits	Fair access	Food	Processing and export	Habitat	Species structure	Resilience
3	3	Sustainable resource									
4	1	Information and monitoring	1	1	1	1	1	1	1	1	1
5	2	Management									
6	10	Profits									
7	8	Fair access									
8	5	Food									
9	4	Processing and export									
10	6	Habitat									
11	9	Species structure									
12	7	Resilience									

Figure 6: Step one of pairwise comparison data entry

1											
2	1: D-W1	Sustainable resource	Information and monitoring	Management	Profits	Fair access	Food	Processing and export	Habitat	Species structure	Resilience
3	3	Sustainable resource	0								
4	1	Information and monitoring	1								
5	2	Management	0								
6	10	Profits	0								
7	8	Fair access	0								
8	5	Food	0								
9	4	Processing and export	0								
10	6	Habitat	0								
11	9	Species structure	0								
12	7	Resilience	0								

Figure 7: Step two of pairwise comparison data entry

2											
3	1: B-W1	Sustainable resource	Information and monitoring	Management	Profits	Fair access	Food	Processing and export	Habitat	Species structure	Resilience
4	3	Sustainable resource	0	0	1	1	1	1	1	1	1
5	1	Information and monitoring	1	1	1	1	1	1	1	1	1
6	2	Management	1	0	1	1	1	1	1	1	1
7	10	Profits	0	0	0	0	0	0	0	0	0
8	8	Fair access	0	0	0	1	0	0	0	1	0
9	5	Food	0	0	0	1	1	0	1	1	1
10	4	Processing and export	0	0	0	1	1	1	1	1	1
11	6	Habitat	0	0	0	1	1	0	0	1	1
12	9	Species structure	0	0	0	1	0	0	0	0	0
13	7	Resilience	0	0	0	1	1	0	0	1	0

Figure 8: Step three of pairwise comparison data entry- a completed sort

#### 2.3.3.3 Disadvantages of the method

For many respondents their general preferences for management objectives could be developed into international policy and then explicit management. This response was expected as the EAF is a relatively new approach that has not yet been implemented.

Respondents struggled with the concept of how the broad principles determined at this early stage could be adapted into more specific policies and programs in the future. Instead, they were more familiar with conventional fisheries management including catch limits, gear regulations and other types of concrete and restrictive actions, rather than the more collaborative models of assessment and governance involved in the Ecosystem Approach to Fisheries (EAF). In response to these reactions, the researcher explained that decisions on management of the fishery would be informed by their feedback and ultimately made by fisheries managers and policy-makers in each government. The researcher informed respondents that the preliminary results of the study would be presented to a delegation of fisheries managers and staff at the 7<sup>th</sup> Annual CRFM Scientific Meeting in June 2011.

Some respondents struggled with the language on the cards. To reduce this problem the researcher went through the cards twice: once with a key sentence to explain the meaning of the card, and a second time with a key word that summarized the sentence mentioned the first time. This strategy was effective, but it is recommended that only one or two key words plus a key image be included on the card, leaving the researcher to interpret the card entirely verbally.

The images used on the cards were an effective memory tool. However since photos were used, the detailed nature of the images proved distracting for some. It is recommended that illustrated graphics be used on the cards rather than photographs. For example, the photo of female processors filleting fish at work could be replaced by graphics of a filleting knife and bag of filleted fish.

#### 2.3.3.4 Advantages of the method

The fact that respondents did not understand how their feedback could have a meaningful contribution to governance reflects the ineffectiveness of past stakeholder consultation efforts, and underscores the need for the type of collaborative management planning attempted in this study.

The method was found to be very effective in determining explicit preferences for different management objectives in a very short time. Time limitations are an unfortunate reality of field work, yet conventional interviews require a significant amount of time to have a meaningful discussion while still meeting all researcher targets. This method enabled the researcher to determine each respondent's specific preferences in only a few minutes while still having time for more unstructured discussion afterwards.

Because the method was a structured and interactive activity, it provided a good ice-breaker to help relax both the respondent and researcher and to start the flow of discussion. It also provided a venue for participation for those who were not interested in discussing the information verbally. Respondents who were not feeling chatty could move the cards around, making a few short statements as they went. In many cases, these respondents would spend a long time thoughtfully organizing their sort, and in some cases would open up after they had finished this exercise. In contrast, a conventional interview requires respondents to openly speak about their values and feelings in front of their peer group as well as a complete stranger.

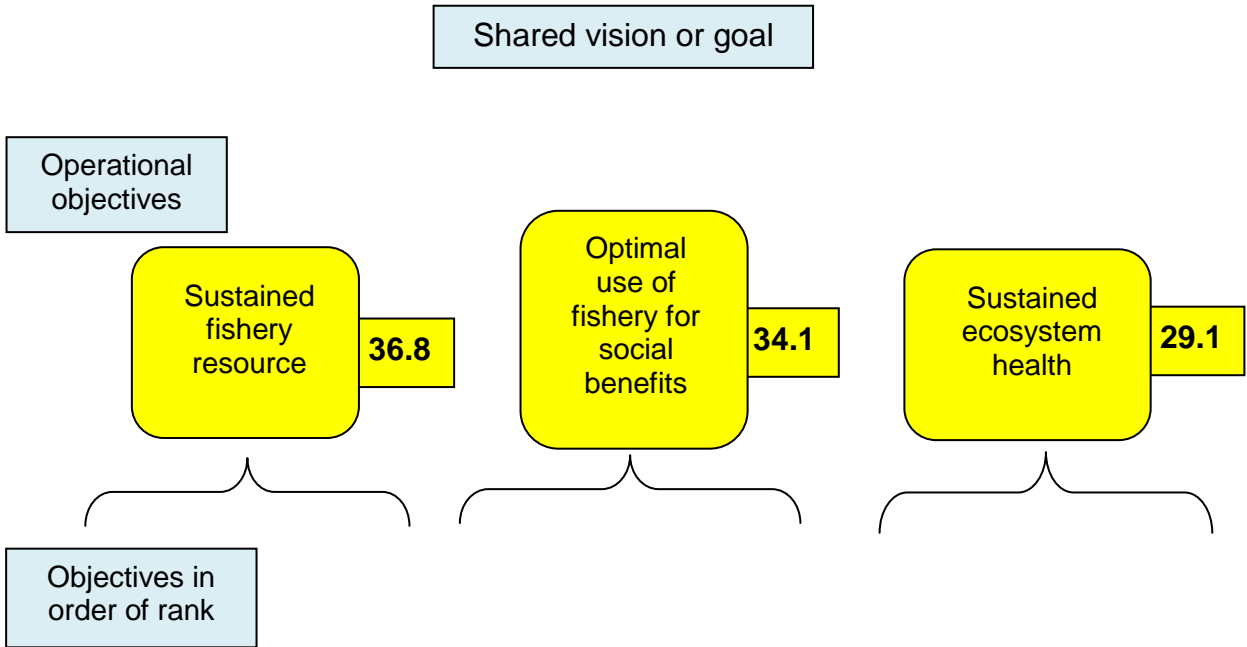
### 3. RESULTS

#### 3.1 Pairwise Comparison Field Surveys

Responses collected during pairwise comparison field surveys in Barbados and Tobago were compiled using the method described above. Results revealed an ordered hierarchy of management objectives in order of importance, demonstrated in Figures 9 and 10. This ranked hierarchy can help guide the management planning process for the Flyingfish fishery.

Average Weights for Each Criteria out of 100 (Rank in Brackets)			
	Total	Barbados	Tobago
Sustainable resource	16.04 (1)	14.42 (2)	20.29 (1)
Habitat	14.22 (2)	15.56 (1)	11.54 (4)
Management	10.59 (3)	9.13 (6)	13.02 (3)
Profits	10.37 (4)	11.27 (3)	8.59 (6)
Processing and export	10.22 (5)	7.51 (8)	14.95 (2)
Information and monitoring	10.19 (6)	9.55 (5)	11.14 (5)
Species structure	7.76 (7)	7.79 (7)	7.58 (8)
Food	7.51 (8)	7.35 (9)	7.71 (7)
Resilience	7.09 (9)	10.53 (4)	0.86 (10)
Fair access	6.00 (10)	6.90 (10)	4.33 (9)

Figure 9: Weighted scores for each objective by nationality with ranking in brackets



<b>1</b>	<b>16.1</b> Sustained	
<b>2</b>		<b>14.2</b> Habitat
<b>3</b>	<b>10.6</b> Effective mgmt	
<b>4</b>		<b>10.4</b> Profits
<b>5</b>		<b>10.2</b> Process & export
<b>6</b>	<b>10.2</b> Info and monitoring	
<b>7</b>		<b>7.8</b> Species structure
<b>8</b>		<b>7.5</b> Food
<b>9</b>		<b>7.1</b> Resilience
<b>10</b>		<b>6</b> Fair access

Figure 10: Weight of operational objective categories and objectives in order of rank

## 3.2 Interview Data for highest Ranked Objectives

### 3.2.1 Sustained Resource

Respondents ranked “Sustained Resource” as the most important management objective, with a total weight (percent importance) of 16.04. In discussion, respondents indicated that sustaining the fishery resource for future generations was of foundational importance and should be an overall goal of management. Respondents stressed that “without fish, no [one] can survive (R5, Bridgetown)” and “without the resource, none of this matters (R11, Consett Bay)”. The importance of sustaining the resource for the long term was repeatedly emphasized as a basic foundational principle of management: one respondent simply shrugged, tapped the Sustained Resource card and said, “For generations (R33, Pigeon Point).”

The Sustained Resource objective was also frequently described as being inseparable from or dependent upon some or all of the other objectives. Several respondents suggested that measuring the health of other objectives could act as an indicator to whether the resource is being sustained and vice versa. For example one respondent in Bridgetown, Barbados said that Sustained Resource is a measure of the health of Species Structure, Habitat, and Food Security- that if the resource is being harvested unsustainably these three other management objectives will be directly affected.

***The overarching importance of Sustained Resource over all other objectives was also heavily emphasized. One respondent stacked the cards in a pile with Sustained Resource on top and explained, “Everything is dependent on this (R36, Scarborough).” Another respondent finished his sort then slid the Sustained Resource card across the table away from the other cards. “These ones are important, but this-” he explained while gesturing to the Sustained resource card “- this is resilience (R37, Scarborough).”***

In Barbados respondents also emphasized the importance of Flyingfish to traditional culture and daily life, because “Flyingfish is what most Bajans are about (R7, Bridgetown),” and emphasized that the sustainability of the stock is deeply tied to the future of Barbados.

Despite overwhelming agreement on the importance of sustaining the Flyingfish stock, respondents did not agree on whether current harvest rates are sustainable. Some respondents believed that regardless of fishing effort, “you can’t overfish with Flyingfish because it’s seasonal (R18, Westin)” and “there’s no danger of overfishing. . . when they’re plentiful there are millions (R19, Bridgetown)”. Some expressed uncertainty about the state of the stocks: “at the end of the day, we don’t know if we’re over-fishing or not. . . [there are] no studies on migration, where they travel, their birth rate, number of eggs, et cetera (R14, Oistins).” Others, however, believed that the stock is being overfished, and – critically – that a lack of management or effective monitoring is contributing to this problem. One respondent cited chronic overfishing as a result of “people looking for a dollar [and you] can’t catch them (R23, Bridgetown).” The same respondent linked unsustainability of the resource to negatively affecting progress on the other objectives, because you “need this [Sustained Resource] before you can get everything else.”

### 3.2.2 Healthy Habitat

Respondents ranked habitat as the second highest management objective that they believed should be optimized, with a weighted score of 14.22 out of 100. This objective was ranked as most important in Barbados (15.56) and fourth most important in Tobago (11.54). Habitat health was identified as a key to sustaining the fishery in the long term, but was also linked to the health of the wider ocean. “The reef is survival,” a respondent in Pigeon Point explained, “it has an important part to play (R37).”

### 3.2.3 Concerns about Pollution

In discussion of the Healthy Habitat objective, respondents in both countries indicated concern about the effects of runoff and pollution on nearshore reefs. A processor who worked in de-boning and filleting Flyingfish ranked Healthy Habitat as her most important objective and simply explained, “we should not pollute the sea (R14, Oistins).” This runoff was linked to tourism development as well as chemical runoff from agriculture. A respondent from Consett Bay specifically cited wastewater pollution at a certain hotel development as negatively affecting what “used to be a nice coral reef . . . higher water temperature kills the reef (R12).” Similarly a respondent from Oistins cited habitat effects from “chemicals from sewage processing at hotels . . . . . fish are not on the reef like they used to be (R15).

Another respondent identified negative effects of chemical runoff from plantation-style agriculture: “a high percentage of reefs are dead, pesticides and herbicides . . . I’ve noticed coral bleaching over the years and [we] are seeing less fish (R17, Westin).” A Consett Bay respondent also cited herbicide runoff as a problem (R9). Runoff was identified in Tobago as well, with one respondent indicating that there is “runoff more than before, we have to go further to get fish (R25, Scarborough).”

### 3.2.4 Confusion about Habitat Governance

In addition to concerns about pollution, respondents also raised the issue of governance, or more specifically, how policies could be developed to optimize the Healthy Habitat objective since it is difficult to manage or manipulate transboundary marine habitat. When the Healthy Habitat card was presented, respondents frequently commented that “well, this is important. . . but you can’t really manage that, can you?”

This uncertainty is warranted since marine habitats are affected by so many external sources that it is incredibly difficult to control them, and are so complex due to the mobility and diversity of marine species that it is nearly impossible to manipulate them for restoration. However, management of marine health can be targeted through other venues, such as controlling terrestrial run-off and establishing rules and guidelines regarding offshore disposal of materials at sea. The challenge of this type of indirect management is coordination between agencies and industry groups at the national and regional levels. A Barbadian respondent raised this issue when discussing how managing habitat is currently outside the jurisdiction of the Fisheries Division. He suggested that since habitat is broader-scale than fisheries, it would be more the responsibility of Coastal Zone Management, and that there is also no such body for managing habitat between countries (R24, Bridgetown).

### 3.2.5 Management

Effective management of the Flyingfish fishery was a well-supported objective, with a weight of 10.34 overall and 9.13 and 13.02 for Barbados and Tobago, respectively. Respondents did not perceive of “management” as a form of regulating catches to manage stocks. In fact, only two out of 37 respondents mentioned catch-limiting as a management approach: the owner of a Barbadian processing business said that he would “support quotas if there was a threat” and suggested gear regulations as one form of management (R18, Bridgetown); an administrative staff member from Barbados supported regional governance because “management is the way to sustain the resource” but emphasized that “true political will [is needed] to manage the fisheries at the regional level in a realistic manner (R24, Bridgetown)”.

Overall, while a few respondents believed that “you can’t overfish because Flyingfish is seasonal (R13, Oistins)”, all but one of these individuals ranked Management within their top 2 objectives. This indicates that even while they believe overfishing is not an issue, they still value the importance of managing the Fishery.

### 3.2.5.1 Management as Industry Development

However, most respondents, understood “management” to be government support for developing the fishery and improving the business of harvesting Flyingfish. The most commonly cited form of management was development of sanitary facilities for processing and storage. Food safety and sanitation were key concerns, because “icing and handling not always done as it should be (R25, Scarborough), and “sanitation, health and safety are key (R14, Oistins).” Poor sanitation and storage resulting in spoiled or low quality fish were identified as limiting factors in selling Flyingfish. These problems were all linked to the lack of processing and storage facilities, particularly at small landing sites: “we need a storage facility. . . no resources especially during the height of the season (R30, Pigeon Point)”; “proper landing sites equals better sanitation (R35, Pigeon Point). The need for other infrastructure including proper slipways was also identified, particularly by fishers in Tobago.

### 3.2.5.2 Appropriate Bodies for Management: Government Versus Co-op

In terms of *whom* respondents believed should be providing this management support, respondents in Tobago referred to the national government while Barbadian respondents more frequently mentioned co-ops. In Tobago, respondents frequently called for the government to provide development including better facilities, “proper equipment at different landing sites (R29, Buccoo);” “more rafts to increase spawning (R26, Scarborough);” and assistance in developing a market for Flyingfish products, including an idea where “Tobago House of Assembly could buy and sell from fishermen, create a market (R31, Pigeon Point).” In Barbados, however, respondents more commonly referred to co-ops and a need to “start from the bottom up” despite the fact that “co-ops can’t get together. . . break down” because “people don’t work together or help each other out (R12, Consett Bay).” Similarly, a fisher from Westin lamented that while “management is key,” he “[doesn’t] think government would work . . . and co-ops never get off the ground” based on his experience in trying to get one going (R17, Westin).

### 3.2.5.3 Security and Enforcement

Security was also identified as an issue in Tobago because equipment is frequently stolen from landing sites. On the day of the interviews in Buccoo, a day boat was being lifted out of the water because two motors had been stolen off from it the night before. Underscoring the lack of appropriate infrastructure, the boat was lifted out by a rented crane at significant cost because the Buccoo port lacks a proper slipway. Respondents at the scene lamented the lack of security and facilities, and suggested that lights on the pier and a security presence would increase the security of their livelihood by protecting essential boats and equipment.

Similarly, enforcement of both “sanitation rules – existing supervisors don’t enforce them (R17, Westin)” and illegal fishing were called for, because there’s “no sense making policy if we can’t enforce it (R36, Scarborough).” The issue of legal versus traditional fishing boundaries is far beyond the scope and focus of this study. However it is worth mentioning that several (not all) Barbadian fishers freely admitted to fishing within what are technically Tobagonian waters. The Barbadians identified these waters as their traditional fishing grounds. Some Tobagonian fishers, particularly those at Pigeon Point, are familiar with several Barbadian vessels which fish inside the legal Tobago boundary and consider them fellow fishers in the same industry rather than a threat.

This geniality does have its bounds, however: Tobago respondents were concerned about boundary issues in cases where multiple foreign vessels were fishing within Tobago waters. One fisher at Pigeon Point explained that while he knows many of the Barbadian fishers and doesn’t mind them being within the Tobago boundary, he was concerned about harvesting from other international vessels, calling for “policing of Flyingfish...[because] Spanish and Barbadians are only 16 miles off the coast of Tobago... sometimes 24 vessels per day (R37).” His views summed up many comments from Tobagonian

respondents on the issue: it's not the presence of Barbadian vessels within Tobagonian waters, but rather the proximity of their fishing operations to the Tobago coast and amount of vessels present that result in concern.

### **3.3 Cluster Analysis**

Hierarchical cluster analysis was utilized to group respondents with similar perspectives. This data set has ten variables and a response range of zero to eight – a significant amount of response variability; however, cluster analysis facilitates analysis of these data by grouping respondents according to their perspectives. Specifically, this method is useful for identifying groups of individuals who are similar to each other but different from individuals in other groups. Both hierarchical and k-means cluster analysis were conducted in SPSS 16.0 for this analysis.

#### 3.3.1 Hierarchical Cluster Analysis

Hierarchical cluster analysis was used to identify degrees of difference in respondent perspectives at different stages in the analysis. Respondents with the most strongly similar perspectives are grouped in the first stage, and then additional respondents or clusters are added as similarities are identified at different stages. This means that respondents remain in their initial cluster and are not separated or moved, and their cluster can only be combined with another cluster or individual. The hierarchical cluster analysis output is represented in a dendrogram, below (Figure 11).

This analysis pinpoints similarities between specific individuals or groups of individuals, and the stages at which groups formed and combined (indicating their relative strength). Cluster groupings can also be identified from the analysis. A solution for four clusters is illustrated below in Figure 11 with colours indicating the different groupings. This agglomeration schedule supporting this solution is presented in Appendix B.



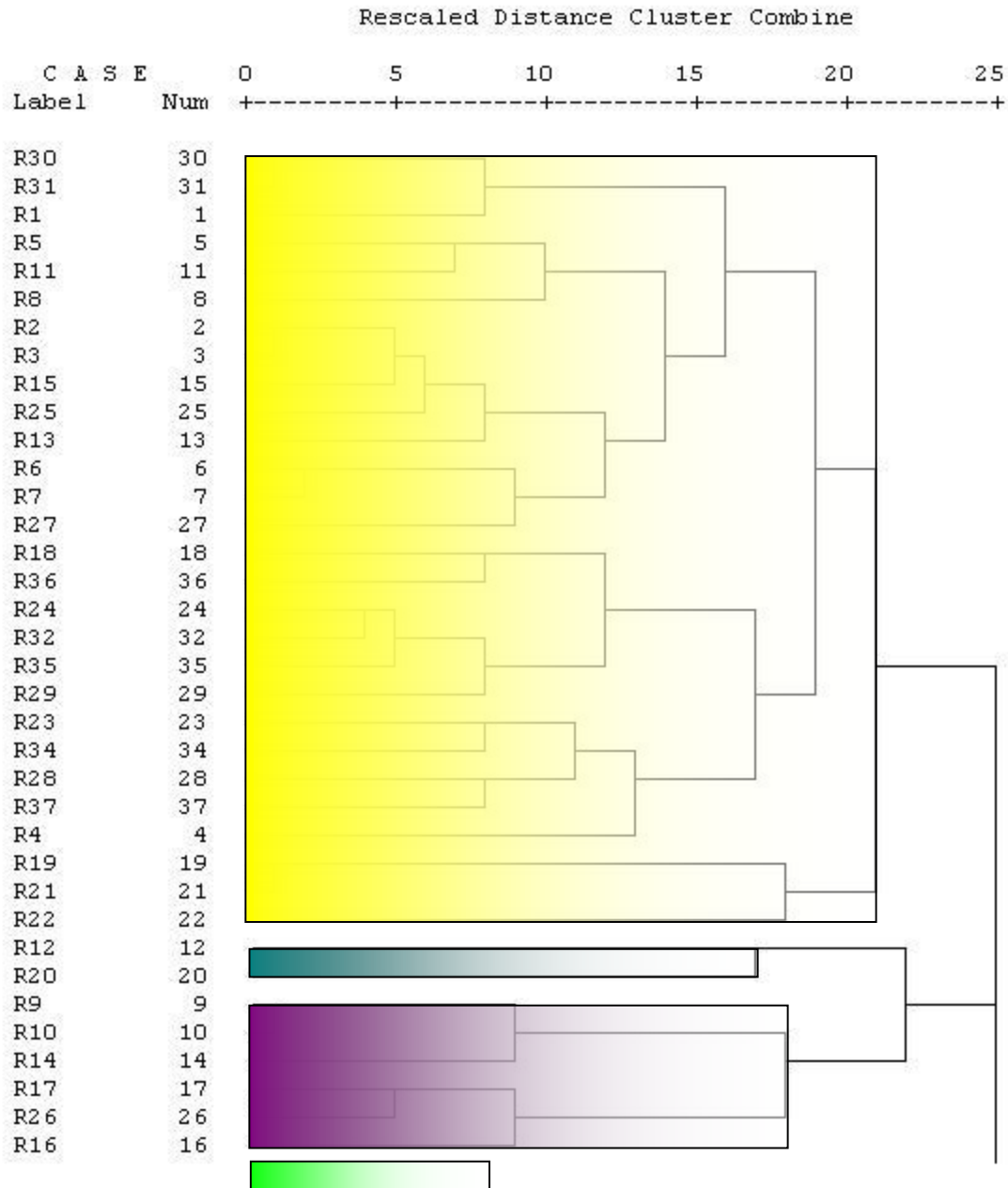


Figure 11: Dendrogram indicating cluster groupings in the following colours: Cluster 1, yellow; Cluster 2, blue; Cluster 3, purple; Cluster 4, green.

### 3.3.2 K-means cluster analysis

A second type of clustering, k-means analysis, was conducted to augment the hierarchical analysis. Unlike the hierarchical method, k-means analysis does not retain respondents in the first cluster they joined. Instead, respondents are switched from cluster to cluster depending on the new cluster center that forms as individuals are added. This iterative method allows the clusters to evolve as their membership changes. Cluster centers can be understood as idealized representations of each group – essentially the heart of the cluster group which differentiates it from the others. Clusters are formed when objects are

assigned to the nearest centroid. There are two key drawbacks of this method. The first is that because the analysis is so focused on the cluster center the boundaries between clusters can be fuzzier, and individual membership for those at the edges of their cluster is less clearly justified. The hierarchical method included above supplements this weakness by demonstrating linkages between individuals and small groups of individuals. Even though the final cluster membership may differ between the two analyses, the hierarchical analysis focuses on individual similarities at different stages while the k-means focuses on similarities to foundational group centres.

Cluster Membership					
Respondent	Nationality	Occupation	Boat Type	Cluster	Distance
1	BDS	Fisher	Day	1	6.684
2	BDS	Fisher	Ice	1	6.076
3	BDS	Fisher	Ice	1	6.665
5	BDS	Fisher	Ice	1	7.066
11	BDS	Fisher	Day	1	8.996
19	BDS	Processor		1	8.272
21	BDS	Processor		1	8.272
37	TT	Fisher	Day	1	8.598
9	BDS	Fisher	Day	2	8.681
10	BDS	Fisher	Day	2	8.681
12	BDS	Fisher	Day	2	10.393
24	BDS	Admin		2	7.089
28	TT	Fisher	Day	2	5.520
30	TT	Fisher	Day	2	8.434
31	TT	Fisher	Day	2	8.434
33	TT	Fisher	Day	2	9.001
36	TT	Admin		2	10.248
14	BDS	Processor		3	7.659
16	BDS	Fisher	Ice	3	7.095
17	BDS	Fisher	Day	3	7.257
20	BDS	Processor		3	10.786
23	BDS	Admin		3	6.110
26	TT	Fisher	Ice	3	6.831
4	BDS	Fisher	Ice	4	9.204
6	BDS	Fisher	Ice	4	6.719
7	BDS	Fisher	Ice	4	6.949
8	BDS	Fisher	Ice	4	8.635
13	BDS	Fisher	Day	4	9.258
15	BDS	Fisher	Ice	4	8.018
18	BDS	Processor		4	10.730
22	BDS	Processor		4	10.677
25	BDS	Fisher	Ice	4	6.918
27	TT	Fisher	Day	4	7.358
29	TT	Fisher	Ice	4	7.521
32	TT	Fisher	Day	4	8.341
34	TT	Processor		4	10.156
35	TT	Processor		4	8.053

Figure 12: Cluster membership of each respondent with Euclidian distance from cluster centre

The second weakness of k-means is that the number of clusters must be explicitly programmed into the analysis. Again, the hierarchical method supplements this weakness by facilitating selection of an ideal number of cluster groups. In this case, interpretation of the data suggested that four was the ideal number of cluster groups.

### 3.3.3 Cluster Membership

The chart in Figure 12 indicates the membership of individuals in each cluster. Respondents identified by their respondent number are listed in their respective clusters alongside information on their occupation, nationality, boat type (if applicable), and their Euclidian distance from the cluster center. This measure of distance indicates how far their perspective strays from the core perspectives at the heart of the cluster center.

### 3.3.4 Characteristics of Cluster Groups

As discussed above, the cluster centers represent the core viewpoint of each cluster group. Figure 13 summarizes the objectives in order of importance for each group. The numerical scores in the table have significance in decreasing order. These scores reference the order in which respondents in the group sorted the cards. A score of 8 indicates that, on average, the group arranged this card in the highest possible position. Due to extreme variation in sorts it is highly unlikely for very multiple high scores to emerge, if any do at all. Accordingly, a very high score is considered to be 6-8, a fairly high score is considered to be 4 or 5, a fairly low score is considered to be 3, and a very low score is considered to be below 3. In the descriptive analysis of the data which follows, discussion will focus on objectives which received high rankings rather than low rankings. This is because respondents generally started the sorting process by selecting their most important objectives in order; then filled in the rest of the sort with the rest. While the order of their preferences is believed to be accurate, it is less certain whether objectives listed here with a score of 1 were considered by respondents to be extremely unimportant, or whether they were considered to be less important than the other seven objectives.

Final Cluster Centers							
1		2		3		4	
Objective	Score	Objective	Score	Objective	Score	Objective	Score
Sustained.resource	8	Food	6	Habitat	5	Sustained.resource	8
Management	7	Habitat	5	Profits	4	Profits	5
Habitat	5	Info.monitor	5	Resilience	4	Species.structure	4
Info.monitor	5	Management	4	Info.monitor	2	Fair.access	4
Resilience	4	Species.structure	3	Sustained.resource	1	Management	3
Processing.export	4	Sustained.resource	2	Food	1	Processing.export	3
Fair.access	3	Fair.access	2	Management		Info.monitor	3
Profits	2	Processing.export	2	Fair.access		Habitat	3
Food	2	Profits	1	Processing.export		Food	2
Species.structure	1	Resilience		Species.structure		Resilience	1

Figure 13: Cluster centres indicating the representative set of objective rankings of each cluster group

### 3.3.5 Cluster 1

Cluster 1 respondents ranked Sustained Resource as the most important objective with a very high score (8), closely followed by Management (7). This suggests that these respondents identify linkages between effective management and sustainable harvest of the Flyingfish resource. The ecosystem-scale priorities of Habitat and Resilience were both assigned fairly high scores (5 and 4), as well as the managerial priorities of Information and Monitoring and Processing and Export (5 and 4).

Seven of the eight respondents in this group were Barbadian, with only one Tobagonian. There was equal representation of ice boat and day boat fishers, with two processors.

#### 3.3.6 Cluster 2

Cluster 2 was the only grouping which highly valued food security and availability of Flyingfish by ranking Food as a management priority (6), and also differed by assigning Profits the lowest score (1) out of any grouping. Like Clusters 1 and 3, this group assigned Habitat a fairly high score (5). Cluster 2 respondents also highly valued the administrative objectives of Information and Monitoring (5) and Management (4).

Membership of this group consisted primarily of day boat fishers as well as two administrative staff (out of a possible three). Nationality of the nine members in this group was split between five Tobagonians and four Barbadians.

#### 3.3.7 Cluster 3

Cluster 3 respondents assigned Resilience (4) the highest score out of all other groupings, tying it as their second most important objective. Habitat and Resilience are both ecosystem-scale components of fishery health; accordingly, these high rankings indicate that this group supports considers the fishery and its health at the ecosystem scale. Furthermore, this group tied the Profits and Resilience objective, suggesting strong linkages between financial health and resilient, healthy habitats and ecosystems.

This group had the smallest membership, with only six individuals. However, occupational representation in this group was very balanced, with two ice boats, one day boat, two processors and two administrative staff. Six respondents in this group are Barbadian with one Tobagonian. Habitat received the highest ranking for this cluster group.

#### 3.3.8 Cluster 4

Like Cluster 1, Cluster 4 respondents assigned Sustained Resource the highest possible score; however Cluster 4 differed by ranking Management significantly lower than Cluster 1, assigning it only a score of medium importance (3). This group also ranked Information and Monitoring similarly low (3). Instead, Cluster 4 respondents prioritized both Profits (5) and Fair Access (4). Species structure was also ranked fairly high (4), suggesting an appreciation of the importance of age dynamics in fish stocks for sustaining the resource that these respondents valued so highly.

Cluster 4 was the largest group with 14 respondents, including nine Barbadians and five Tobagonians. Representation of ice boats was higher than day boats (seven to three), and there was also a high number of processors (four out of a possible eight).

#### 3.3.9 Similarity and Dissimilarity Between Clusters

The Euclidian distance between the cluster centers indicates how similar and dissimilar the clusters are from each other. Larger numbers indicate greater difference in perspective and smaller numbers indicate similarities. In Figure 14, it is evident that Clusters 1 and 3 are the least similar, due to their dramatically different respective scores for Sustained Resource (8 vs. 1), and Management (7 vs. 0), and Information and Monitoring (5 vs. 2). However, note that Clusters 1 and 3 were identical in their ranking of Habitat (5). In Figure 17 it is also evident that Clusters 1 and 4 are the most similar out of all groupings. This is likely primarily due to their identical high rankings for Sustained Resource (8), because aside from this score they do not appear to be significantly similar. The most similar scores are, respectively, Habitat (5 vs. 3), Information and Monitoring (5 vs. 3), Processing and Export (4 vs. 3), and Profits (2 vs. 5).

### Distances between Final Cluster Centers

Cl...	1	2	3	4
1		8.827	11.382	7.058
2	8.827		9.523	8.977
3	11.382	9.523		10.496
4	7.058	8.977	10.496	

*Figure 14: Variation in perspectives between clusters measured by Euclidian distance*

#### 3.3.10 Significance of variables to cluster centres

An ANOVA analysis indicates which variables contribute the most to the clustering solution. Lower mean square numbers mean that the variable contribute the most to the cluster solution; small numbers indicate the key variables which differentiate between clusters. In this case, respondents' ranking of the Management and Resilience objectives was the largest factor in determining cluster characteristics. Conversely, Sustained Resource is the least influential differentiating between factors- that is, this objective was widely supported and did not divide respondent opinions (Figure 15).

#### ANOVA

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Sustained.resource	116.430	3	3.073	33	37.887	.000
Info.monitor	14.716	3	10.266	33	1.434	.251
Management	52.778	3	6.445	33	8.189	.000
Profits	50.331	3	8.055	33	6.248	.002
Fair.access	16.570	3	7.128	33	2.325	.093
Food	42.332	3	7.013	33	6.036	.002
Processing.export	16.612	3	7.917	33	2.098	.119
Habitat	11.514	3	10.136	33	1.136	.349
Species.struct	25.678	3	9.577	33	2.681	.063
Resilience	28.823	3	6.918	33	4.166	.013

*Figure 15: An analysis of variation using Euclidian mean square to indicate how influential each objective was in forming the cluster centers*

### 3.4 Correlations

While the rankings reveal the agglomerated preferences of all respondents, analysis of correlations between pairs of variables reveals links that respondents identified between objectives. A 2-tailed Pearson bivariate correlation analysis was conducted in SPSS 16.0. Correlation was determined significant at the 0.05 level as is commonly accepted. Pearson correlation was selected because the data range allowed for a

complete lack of importance (zero). The Management objective was most frequently correlated to other objectives. Specifically, Management was strongly correlated with Sustained Resource (.393), Information and Monitoring (.384) and Processing and Export (.366). Processing and Export was in turn strongly correlated to Fair Access (.391). Figure 16 indicates linkages between highly correlated objectives.

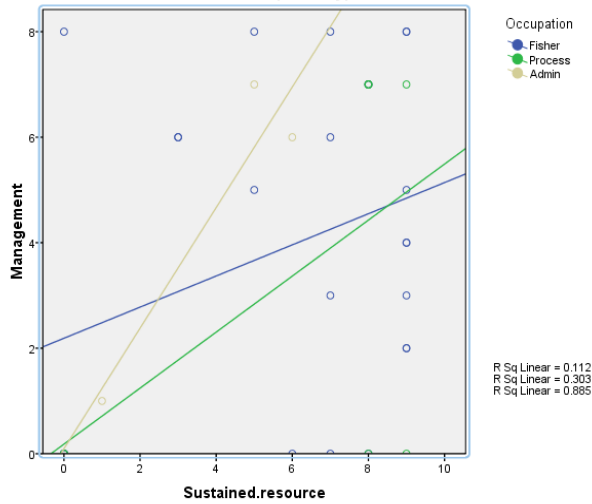
The scores in the table in Figure 16 demonstrate total correlation scores for objective rankings. However when these correlations are broken down by occupation, nationality or boat type, significant variation emerges. The nine graphs within Figures 17, 18 and 19, below, demonstrate linear correlations between the three highest-ranked objectives, and are repeated for the occupation, nationality and boat type categories. Variation is evident within these comparisons, however for the most part the linear correlations are parallel and views are fairly similar on the linkages between these three most important objectives.

Correlations											
		Sustained.resource	Info.monitor	Management	Profits	Fair.access	Food	Processing.export	Habitat	Species.struct	Resilience
Sustained.resource	Pearson Correlation	1.000	.078	.393*	.229	.294	-.244	.323	-.237	.183	-.026
	Sig. (2-tailed)		.647	.016	.172	.077	.146	.051	.158	.279	.878
	N	37.000	37	37	37	37	37	37	37	37	37
Info.monitor	Pearson Correlation	.078	1.000	.384*	-.023	.133	.080	.094	-.100	-.179	-.175
	Sig. (2-tailed)	.647		.019	.891	.433	.637	.579	.556	.289	.300
	N	37	37.000	37	37	37	37	37	37	37	37
Management	Pearson Correlation	.393*	.384*	1.000	-.235	.128	.181	.366*	-.143	.080	-.045
	Sig. (2-tailed)	.016	.019		.161	.451	.285	.026	.397	.639	.790
	N	37	37	37.000	37	37	37	37	37	37	37
Profits	Pearson Correlation	.229	-.023	-.235	1.000	.228	-.302	.177	.098	-.079	-.104
	Sig. (2-tailed)	.172	.891	.161		.174	.069	.293	.563	.641	.540
	N	37	37	37	37.000	37	37	37	37	37	37
Fair.access	Pearson Correlation	.294	.133	.128	.228	1.000	-.135	.391*	.257	.070	-.009
	Sig. (2-tailed)	.077	.433	.451	.174		.424	.017	.124	.679	.956
	N	37	37	37	37	37.000	37	37	37	37	37
Food	Pearson Correlation	-.244	.080	.181	-.302	-.135	1.000	.091	-.011	.254	-.220
	Sig. (2-tailed)	.146	.637	.285	.069	.424		.592	.950	.129	.190
	N	37	37	37	37	37	37.000	37	37	37	37
Processing.export	Pearson Correlation	.323	.094	.366*	.177	.391*	.091	1.000	.220	-.131	.071
	Sig. (2-tailed)	.051	.579	.026	.293	.017	.592		.190	.439	.675
	N	37	37	37	37	37	37	37.000	37	37	37
Habitat	Pearson Correlation	-.237	-.100	-.143	.098	.257	-.011	.220	1.000	-.138	.057
	Sig. (2-tailed)	.158	.556	.397	.563	.124	.950	.190		.417	.736
	N	37	37	37	37	37	37	37	37.000	37	37
Species.struct	Pearson Correlation	.183	-.179	.080	-.079	.070	.254	-.131	-.138	1.000	-.252
	Sig. (2-tailed)	.279	.289	.639	.641	.679	.129	.439	.417		.132
	N	37	37	37	37	37	37	37	37	37.000	37
Resilience	Pearson Correlation	-.026	-.175	-.045	-.104	-.009	-.220	.071	.057	-.252	1.000
	Sig. (2-tailed)	.878	.300	.790	.540	.956	.190	.675	.736	.132	
	N	37	37	37	37	37	37	37	37	37	37.000

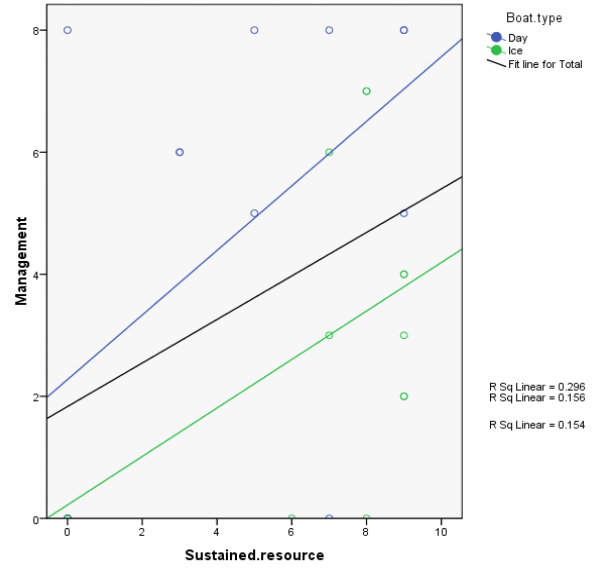
\*. Correlation is significant at the 0.05 level (2-tailed).

Figure 16: Correlation table with asterisks (\*) indicating statistically significant scores

Correlation between management and sustaining the resource among occupation types



Correlation between management and sustaining the resource among day and ice boat fishers



Correlation between management and sustaining the resource among Barbadian and Tobagonian respondents

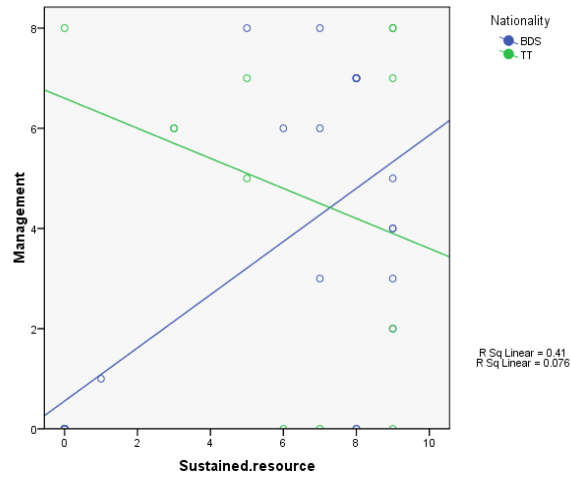
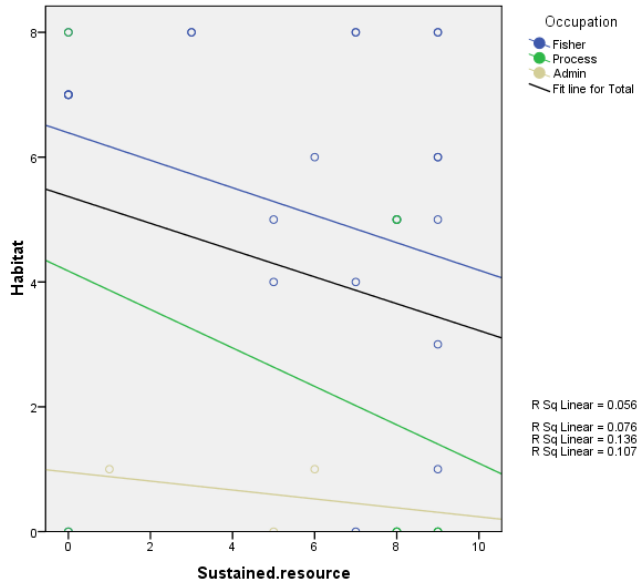


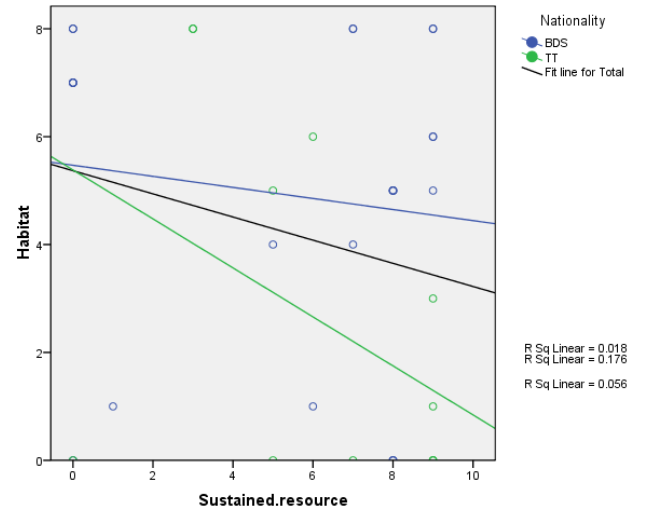
Figure 17: Correlations between management and sustaining the resource by occupation type, boat type, and nationality



Correlation between habitat and sustained resource by occupation type



Correlation between habitat and sustained resource by nationality



Correlation between habitat and sustaining the resource by boat type

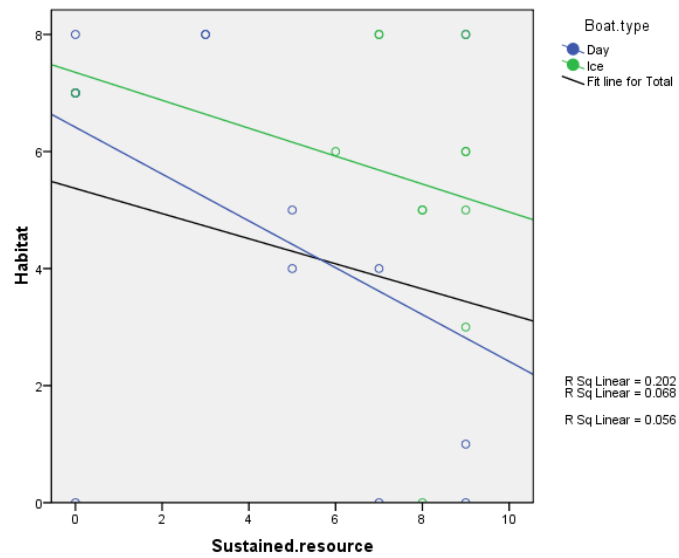


Figure 18: Correlations between habitat and sustaining the resource by occupation type, boat type, and nationality

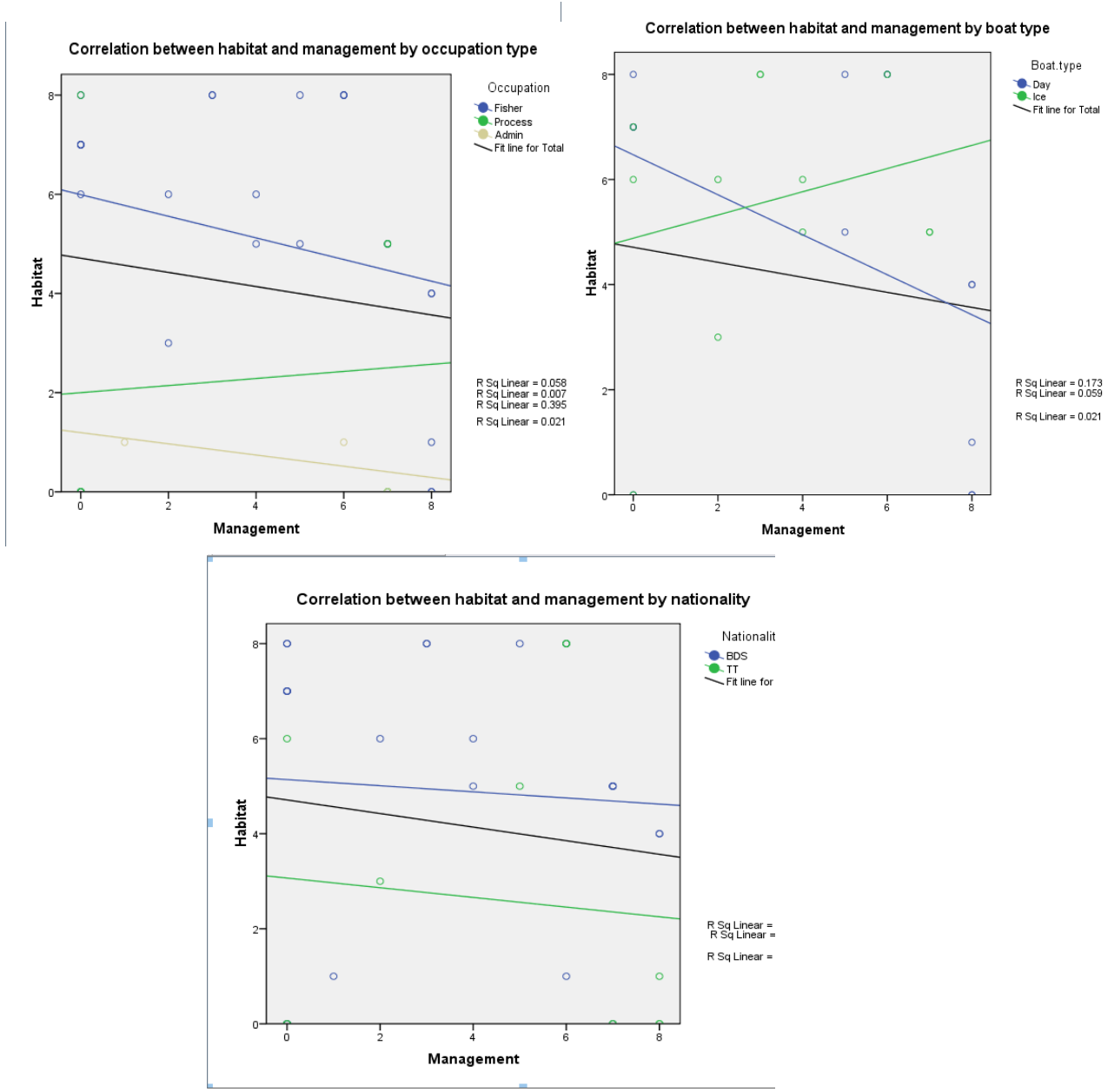


Figure 19: Correlations between habitat and management by occupation type, boat type, and nationality

## 4. DISCUSSION

### 4.1 Sustaining the resource as key overarching objective

Sustained Resource was overwhelmingly supported as the most important management objective. It was the most highly ranked objective based on the weighted average for all respondents (15.66), as well as among both Barbadians (14.04) and Tobagonians (20.29). 75% of processors and 73% of ice boat fishers and processors ranked Sustained Resource as their most important or second most important objective, followed by 50% of Barbadians, 38% of Tobagonians, and 21% of day boat fishers. Those who did not rank Sustained Resource as one of their top objectives often believed that it was satisfied by other objectives like habitat or resilience. However, some respondents ranked Sustained Resource lower than

other objectives because they believed that the seasonal lifecycle of the Flyingfish means that it cannot be overfished.

Regardless of how highly respondents ranked Sustained Resource, nearly all emphasized the overall importance of this objective and how deeply integrated it is to all the others. In fact, it was identified as being so interconnected and interdependent with the other objectives that all other objectives can be nested within the overall goal of Sustained Resource.

In summary, the importance of Sustained Resource as a management objective was emphasized in the following ways:

- Respondents overwhelmingly identified Sustained Resource as the most important objective
- Other objectives are interconnected with and even nested within Sustained Resource
- Support for this objective suggests that there is significant stakeholder support for Sustained Resource as the primary and overarching goal of in the regional management of Flyingfish

#### **4.2 Willingness to participate in management and governance**

Overall, fishers did not indicate strong disagreement with the *idea* of managing the fishery: where there was resistance to management it was due to doubts about whether such a complex and multi-national endeavour is feasible; or due to concerns that regulation would result in excessive restrictions or limitations to their fishing activities.

Critically, respondents also indicated interest in continuing to discuss their interests and priorities for fisheries management, provided that their concerns were taken seriously and incorporated in a meaningful way. As R33 (Pigeon Point) suggested, “we need to make it better for the fishermen... talk to them, find out what they need.” This demonstrates a willingness to participate in management planning in the future if it is truly collaborative.

#### **4.3 Management as monitoring and industry development**

Management was cited as the third most important management objective overall (10.34), but was also strongly linked to the success of other highly ranked objectives. Specifically, Management was highly correlated with Sustained Resource (15.66), Information and Monitoring (9.95), and Processing and Export (9.98).

Respondents often attributed the failing market for Flyingfish and lack of processing and export opportunities as a failure in management. Pricing was also cited as an issue related to management. Suggested resolutions included the establishment of facilities for processing and storage to ride out booms and busts in the market. Opinion was divided on whether this type of management should occur through a co-op or through existing government mechanisms. Regardless of the management body, for most respondents, management of the fishery was not understood to be quotas and catch restrictions; it was, rather, understood as institutional support for post-production, improving the market for Flyingfish, and improving benefits for those who participate in the industry. Support for management was highest among day boat fishers and Tobagonians, who were most likely to rank management as the most important or second most important objective.

In summary these high objectives rankings combined with the correlation between them indicate the following:

- Respondents are in support of managing the resource

- Respondents believe management will contribute to sustaining the resource
- Respondents' conception of “management” includes co-op or government-led:
  - Development of the fishery including facilities for storage and processing
  - Data collection, monitoring, and information-sharing on the status of the resource

#### **4.4 The ecosystem approach to habitat**

Through interview discussions and the ranking activity, respondents indicated strong support for sustaining the ecosystem-scale features and functions which support the Flyingfish fishery and ocean health more broadly. For example, habitat was ranked highly by all respondents (13.89) and was the top priority for respondents in Tobago (13.89), and respondents in Barbados ranked Resilience as the fourth most important objective (10.25). In interview comments, respondents indicated a strong awareness of the compounding effects of pollution and overfishing.

More importantly, most respondents drew linkages between these effects at the ecosystem scale. Their understanding of “habitat” was broader than the specific pelagic waters where fish travel and spawn. Instead, they referred frequently to reefs as habitat as well as the foundation of the food chain and the entire ocean system; that the reef is “survival (R37)” and of foundational importance. At the Plenary Session of the Seventh Annual Scientific Meeting where this research was presented, a delegate questioned whether respondents’ references to reefs in consideration of the habitat objective could skew the results. Rather than skew the results, we believe that reference to reefs is a finding of the study rather than a flaw. It demonstrates that respondents understood the idea of habitat as composing the wider ocean environment, including both reef and pelagic ecosystems. This perspective is consistent with the ecosystem approach to fisheries (Fanning *et al.* 2007), where habitat, species, food sources, and other components are not considered in isolation of each other. In this way, respondents demonstrated that their understanding of the ocean environment is already consistent with the ecosystem approach, and high valuation of the wider ocean environment as habitat is a function of this perspective.

In summary:

- Respondents highly valued habitat, but understood it as highly connected to other objectives
- Respondents identified cumulative effects of stress on marine ecosystems
- Respondents conceived habitat as an interconnected ecosystem
  - This perspective is consistent with the ecosystem approach

#### **4.5 Complex Systems Approach to Understanding and Managing the Fishery**

The interconnectedness and interdependence of all objectives was frequently emphasized by respondents. Many indicated that objectives or groups of objectives were highly co-dependent. As mentioned above, respondents also considered the fishery at an ecosystem scale and recognized important linkages within this system. While respondents did not reference complex systems theory or “ecosystem approach” jargon, their conception of the fishery and the objectives which should be optimized to sustain it was dramatically similar to the multi-scalar model of a complex social and ecological system which has intersecting feedback loops and is integrated horizontally and vertically (Folke *et al.* 2004; Fanning *et al.* 2007; see Box 1 in Section 1). However, respondents’ skepticism of how governance could be implemented raise the critical issue that for the ecosystem approach to be integrated in practice, government ministries and divisions must collaborate and integrate both horizontally within nation states and vertically between multiple countries. For example, optimizing an objective like Healthy Habitat is an initiative that crosses several sectors, involving agriculture, fisheries, marine transport and others at the national and international level.

Accordingly, both the fishery *and* the hierarchy of objectives should be understood and communicated as a complex system. Saaty (2008) proposes this method for organizing and understanding objectives ranked through Pairwise Comparison or Analytic Hierarchy Process. As shown in the diagram below (Figure 20), he suggests conceiving of the objectives as organized in a non-linear network and having various dependencies and linkages.

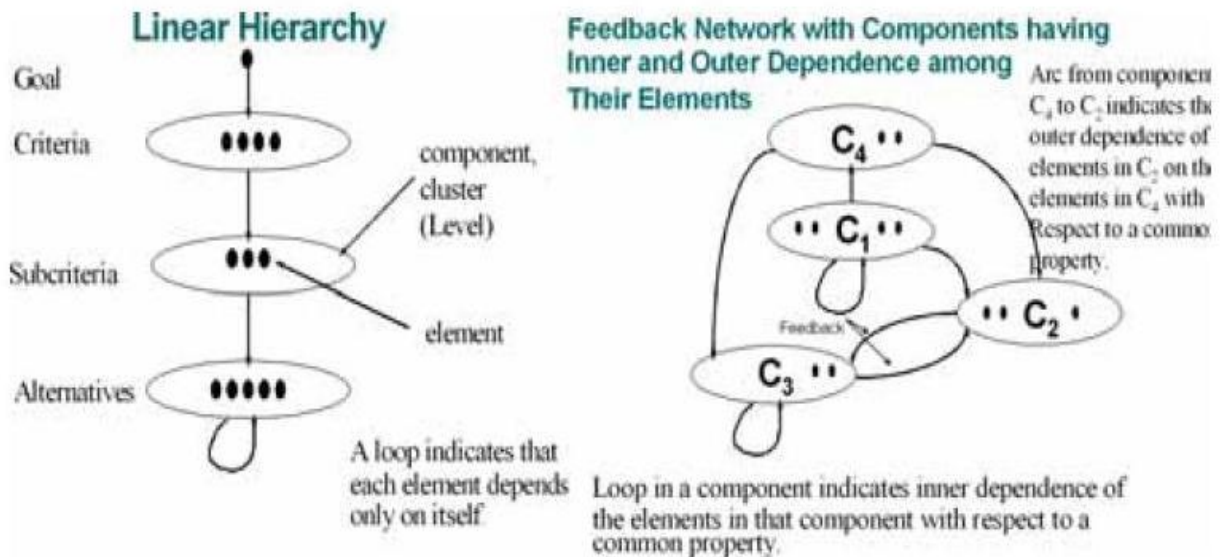


Figure 20: Comparison between a linear hierarchy and feedback network, from Saaty (2008, p. 280).

The network or complex systems approach to representing the scores for objectives indicates the importance of relationships and their foundational dependency upon each other for success.

In summary, this finding suggests that:

- Respondents conceive of the fishery as part of a linked and interdependent complex system
- Evaluation of objective importance of this system should be conceptualized using a complex systems model rather than a linear model
  - This model could guide management by demonstrating the linkages and feedback loops between various objectives

#### 4.6 Next Steps: Determining Performance Scores for Each Objective

To assess the overall health of the fishery, in a second phase of this study these weighted objectives can be multiplied by performance scores for each objective using the method described in Section 2 – MCA as an Assessment Framework.

### 5. ACKNOWLEDGEMENTS

This document is the product of a six month internship at the Caribbean Regional Fisheries Mechanism (CRFM) Secretariat Office in Kingstown, St. Vincent and the Grenadines which took place between January and July 2011. The internship was sponsored by the Canadian International Development Agency (CIDA) through the International Youth Internship Program (IYIP) and was facilitated by the Marine Affairs Program at Dalhousie University. Field work in Barbados and Tobago was sponsored by CRFM.

Many thanks to the partners listed above for sponsoring this study, and heartfelt gratitude to the fishers, fish processors, and fisheries department administrators who graciously volunteered their time to participate.

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## 7. APPENDICES

### Appendix A: Respondent Sorts

Very high rankings (8 and 9) for objectives are highlighted in yellow.

Respondent (R)	Nationality	Occupation	Boat Type	Sustained Resource	Information & monitoring	Management	Profits	Fair access	Food	Processing & export	Habitat	Species structure	Resilience
1	BDS	Fisher	Day	7	9	8	0	2	5	6	4	1	3
2	BDS	Fisher	Ice	8	8	7	6	4	1	2	5	0	3
3	BDS	Fisher	Ice	8	9	7	6	4	1	2	5	0	3
4	BDS	Fisher	Ice	8	7	0	8	0	0	0	0	0	0
5	BDS	Fisher	Ice	7	5	6	0	9	1	4	8	2	3
6	BDS	Fisher	Ice	9	1	2	8	7	0	5	6	4	3
7	BDS	Fisher	Ice	9	1	4	7	8	0	4	6	2	3
8	BDS	Fisher	Ice	7	6	3	5	4	1	0	8	9	2
9	BDS	Fisher	Day						7		7	7	
10	BDS	Fisher	Day						7		7	7	
11	BDS	Fisher	Day	9	1	5	0	6	4	2	8	7	3
12	BDS	Fisher	Day		7			7			7		
13	BDS	Fisher	Day	5	4	8	9	6	0	7	4		
14	BDS	Processor							6	0	8	0	6
15	BDS	Fisher	Ice	9	7	3	6	5	0	4	8	0	0
16	BDS	Fisher	Ice	0	0	0	9	0	0	0	7	0	8
17	BDS	Fisher	Day				9				8		
18	BDS	Processor		8	0	7	0	0	0	0	0	9	
19	BDS	Processor		8	0	7	0	0	0	6	5	0	9
20	BDS	Processor		0	9	0	0	0	0	0	0	0	8
21	BDS	Processor		8	0	7	0	0	0	6	5	0	9
22	BDS	Processor		8	0	0	5	7	5	4	0	0	8
23	BDS	Admin		1	1	1	1	1	1	1	1	1	1
24	BDS	Admin		6	6	6	3	3	9	2	1	5	0
25	BDS	Fisher	Ice	9	7	4	6	2	1	8	5	3	0
26	TT	Fisher	Ice	6			6				6		
27	TT	Fisher	Day	7	0	0	7	5	0	5	0	7	0
28	TT	Fisher	Day	5	5	5	0	0	5	0	5		

29	TT	Fisher	Ice	9	5	2	8	0	7	4	3	6	1
30	TT	Fisher	Day	3	5	6	2	4	7	9	8	1	0
31	TT	Fisher	Day	3	5	6	2	4	7	9	8	1	0
32	TT	Fisher	Day	9	4	8	3	2	7	5	1	6	0
33	TT	Fisher	Day	0	7	8	0	0	9				
34	TT	Processor		9	0	0	0	0	0	8			
35	TT	Processor		9	2	7	4	3	5	6	0	8	0
36	TT	Admin		5	6	7	0	3	2	1	8	9	4
37	TT	Fisher	Day	9	6	8	0	0	0	0	7		



*Appendix B: Supplemental data on selected cluster solution*

**Cluster Membership**

Case	5 Clusters	4 Clusters	3 Clusters	2 Clusters
1:R1	1	1	1	1
2:R2	1	1	1	1
3:R3	1	1	1	1
4:R4	1	1	1	1
5:R5	1	1	1	1
6:R6	1	1	1	1
7:R7	1	1	1	1
8:R8	1	1	1	1
9:R9	2	2	2	1
10:R10	2	2	2	1
11:R11	1	1	1	1
12:R12	3	3	2	1
13:R13	1	1	1	1
14:R14	2	2	2	1
15:R15	1	1	1	1
16:R16	2	2	2	1
17:R17	2	2	2	1
18:R18	1	1	1	1
19:R19	4	1	1	1
20:R20	3	3	2	1
21:R21	4	1	1	1
22:R22	4	1	1	1
23:R23	1	1	1	1
24:R24	1	1	1	1
25:R25	1	1	1	1
26:R26	2	2	2	1
27:R27	1	1	1	1
28:R28	1	1	1	1
29:R29	1	1	1	1
30:R30	1	1	1	1
31:R31	1	1	1	1
32:R32	1	1	1	1
33:R33	5	4	3	2
34:R34	1	1	1	1
35:R35	1	1	1	1
36:R36	1	1	1	1
37:R37	1	1	1	1

Cluster Membership			
Case	Nationality	Cluster	Distance
1	BDS	1	6.684
2	BDS	1	6.076
3	BDS	1	6.665
4	BDS	4	9.204
5	BDS	1	7.066
6	BDS	4	6.719
7	BDS	4	6.949
8	BDS	4	8.635
9	BDS	2	8.681
10	BDS	2	8.681
11	BDS	1	8.996
12	BDS	2	10.393
13	BDS	4	9.258
14	BDS	3	7.659
15	BDS	4	8.018
16	BDS	3	7.095
17	BDS	3	7.257
18	BDS	4	10.730
19	BDS	1	8.272
20	BDS	3	10.786
21	BDS	1	8.272
22	BDS	4	10.677
23	BDS	3	6.110
24	BDS	2	7.089
25	BDS	4	6.918
26	TT	3	6.831
27	TT	4	7.358
28	TT	2	5.520
29	TT	4	7.521
30	TT	2	8.434
31	TT	2	8.434
32	TT	4	8.341
33	TT	2	9.001
34	TT	4	10.156
35	TT	4	8.053
36	TT	2	10.248
37	TT	1	8.598

Iteration	Change in Cluster Centers			
	1	2	3	4
1	7.726	8.717	6.177	7.320
2	1.462	1.029	1.222	.687
3	.955	.912	.000	.000
4	.000	.000	.000	.000

Distances between Final Cluster Centers				
Cluster	1	2	3	4
1		8.827	11.382	7.058
2	8.827		9.523	8.977
3	11.382	9.523		10.496
4	7.058	8.977	10.496	

ANOVA						
	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Sustained.resource	116.430	3	3.073	33	37.887	.000
Info.monitor	14.716	3	10.266	33	1.434	.251
Management	52.778	3	6.445	33	8.189	.000
Profits	50.331	3	8.055	33	6.248	.002
Fair.access	16.570	3	7.128	33	2.325	.093
Food	42.332	3	7.013	33	6.036	.002
Processing.export	16.612	3	7.917	33	2.098	.119
Habitat	11.514	3	10.136	33	1.136	.349
Species.struct	25.678	3	9.577	33	2.681	.063
Resilience	28.823	3	6.918	33	4.166	.013

# TOWARDS AN ECOSYSTEM APPROACH FOR FLYINGFISH FISHERIES IN THE EASTERN CARIBBEAN: AN EVALUATION OF MULTI-CRITERIA ANALYSIS AS A TOOL FOR IMPROVING INFORMATION IN MULTI-OBJECTIVE DECISION-MAKING

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## Abstract

Multi-Criteria Analysis (MCA), together with its data needs, was evaluated as a tool for use in multi-objective, ecosystem-oriented, management decision-making for the Eastern Caribbean Flyingfish fishery. We developed a MCA framework supported by Analytic Hierarchy Processes to identify, organize, and prioritize management and information elements within the fishery. The study also organized and implemented field work to support MCA elements and to integrate these data into the developed MCA framework for analysis. 114 fishery stakeholders from Barbados, Tobago, and St. Lucia were interviewed to elicit their individual priorities for operational management objectives. In all three sampled countries, individuals placed the greatest priority on objectives which support a sustained fishery resource supported by accurate information and monitoring and complemented by effective management strategies. Optimal use of the flyingfish fishery for social benefits was ranked at almost equal priority among the countries; however, the prioritization of individual management criteria within this specific objective differed between countries. In all three surveyed countries ecological objectives and criteria tended to be given a comparatively low priority and often were not identified as important at all.

Analysis of the information obtained during stakeholder interviews reflected a range of conceptual understanding across survey elements and education on management objective topics. While this range of understanding likely affected the prioritization of management elements to some extent, it also revealed the real and existing diversity of flyingfish fishery stakeholder knowledge, views, and values that would pose a challenge for management decision-making. The MCA framework and its components offered an adaptable, systematic, and transparent means by which to organize existing flyingfish management components, to elicit stakeholder priorities for these components in the field, and to organize and display these priorities in a clear hierarchy. In this way, the MCA increased the information that could be considered simultaneously to support more comprehensive and holistic approaches, and hence facilitate multi-objective management decision-making. The MCA and complementary components also provided a relatively cost-efficient and straightforward means of getting more stakeholders engaged in the policy development cycle while minimizing the potential for conflict.

There is a need for those concerned to consider and agree on the development and application of a broader range of indicators and management reference points in view of the multiple objectives to be

considered in an ecosystem-based management scenario. These additional references and indicators will also inform data improvement efforts, which will be necessary for successful application of MCA.

## **1. INTRODUCTION**

The following report documents the results of a data improvement study undertaken as part of an Eastern Caribbean Flyingfish Case Study Consultancy carried out by the Caribbean Regional Fisheries Mechanism (CRFM) under the auspices of the Caribbean Large Marine Ecosystem (CLME) project. This report begins by providing a general background, context, and framework for the issues being explored, as well as an overview of the purpose, goals and objectives of the evaluation of one Multi-Criteria Analysis (MCA) decision-making tool. The study was carried out over two six-month phases in 2011. A summary of phase one activities is provided, with reference to more detailed supporting documents. Phase two activities, presented here for the first time, are provided in detail. Finally, this report integrates the results and discussion of the two study phases and concludes with a summary of the overall findings as well as recommendations and suggestions for further activities.

### **1.1 Background and context**

The eastern Caribbean is primarily comprised of the archipelagic Leeward and Windward Islands, or Lesser Antilles, and their respective territorial seas and 200 nautical miles Exclusive Economic Zones (EEZ). This region is located within the eastern portion of the Caribbean Large Marine Ecosystem (CLME), an expansive, Caribbean-wide, ocean area defined by common ecological features. The eastern Caribbean is home to an abundance of marine resources on which many of the region's inhabitants depend, both directly and indirectly, for their livelihoods and personal well-being (Heileman and Mahon 2008). There are a multitude of open-access and multi-species fisheries, many of which are trans-boundary in nature and therefore shared by the many Small Island Developing States (SIDS) in the region. While the reported combined annual fisheries production of eastern Caribbean countries is relatively small by global standards at just over one hundred thousand tonnes (FAO 2012), these fisheries nevertheless play a crucial social and economic role in the region. In addition to providing a relatively affordable source of domestic food protein and diversifying local economies in a time of unstable global economic trends, these primarily small-scale eastern Caribbean capture fisheries also inject much-needed revenue into island economies every year. They also provide indispensable employment and livelihood opportunities, most notably throughout more developing and rural areas (Béné *et al.* 2007).

However, as with other fisheries resources around the world, the use of and benefits derived from eastern Caribbean fisheries resources are not without conflict. These conflicts arise for several reasons: from competing needs and objectives both within and between countries and marine resource stakeholders, from an inefficient generation and distribution of marine resource benefits, and from concerns over a lack of sustainable use and sector development in an era of global apprehension over the future of fisheries resources (Bennett *et al.* 2001; Blake and Campbell 2007). Situations of conflict are further exacerbated when combined with a lack of adequate information, strategy, cooperation, and support for fisheries management and policy across levels of governance (Chakalall *et al.* 1998). As a result, many fisheries in the eastern Caribbean, and indeed the world, remain unsustainably utilized and managed.

The eastern Caribbean flyingfish (Exocoetidae) fishery provides both an ideal case study for highlighting the complexity of the fisheries management and policy challenges faced both in the eastern Caribbean and in the Caribbean more broadly as well as an opportunity to evaluate how these challenges may be more effectively addressed within a sustainable development framework.

The fishery targets the single most important family of small pelagic fish in the eastern Caribbean (Headley 2009). Flyingfish, in particular the fourwing flyingfish (*Hirundichthys affinis*), are a widely distributed and shared trans-boundary resource. These fish provide an important food, economic, and cultural resource - most notably in Barbados but also in Dominica, Grenada, Martinique, St. Lucia, St. Vincent and the Grenadines, and Tobago (FAO WECAFC 2010) (Figure 1). They are also a major prey species for many economically high-value fish species in the region, as well as a popular bait fish for subsistence and commercial fisheries.

Flyingfish are a comparatively abundant and well-studied family of fishes in the Caribbean. While current total biomass removals are not well known due to the relatively recent and unmonitored growth of bait fisheries, the average annual commercial catch of flyingfish in the eastern Caribbean was estimated to be 2,200 tonnes in 2007 (FAO WECAFC 2010). A more complete description of the flyingfish fishery and its socio-economic importance is described in Oxenford *et al.* (2007).

The overall importance of flyingfish to eastern Caribbean countries, as well as the legal obligation to collaborate in the management of this shared trans-boundary stock is regionally recognized and acknowledged (FAO WECAFC 2010). FAO WECAFC (2010) also outlined an overarching regional management vision for the resource, as well as visions more specific to the harvest and post-harvest sector.

At the country level, the development of Fisheries Management Plans (FMPs), designed to provide a clear vision and structured protocols for national fisheries management action, varies from more detailed sector-based visions with specific mention of flyingfish to draft objectives with a much broader scope. Irrespective of the level of written detail, the language in these national FMPs, as well as in the draft regional plan developed by WECAFC (2010), follows a common theme and language of flyingfish fishery sustainability, development, efficiency, and optimization for the benefit of people in the eastern Caribbean.

While these draft plans often contain a diverse array of social and economic objectives, the notion of achieving success and stability through fisheries management goals and objectives remains firmly rooted in conventional management strategies that are predominantly focused on single-species stock status and optimized yield. However, the biological status of flyingfish is only one of many factors that determine whether this fishery is stable and successful. Of paramount importance in a fishery are the human factors- how people are involved and engaged in a given fishery, and how they define and create its success. The multi-species and trans-boundary nature of eastern Caribbean fisheries and the strong ecological linkages between flyingfish and other fisheries resources means that strong social, economic, and environmental interconnectivity exists between fisheries resources throughout the region. The success and stability of other eastern Caribbean fisheries is therefore inextricably tied to that of the eastern Caribbean flyingfish fishery.

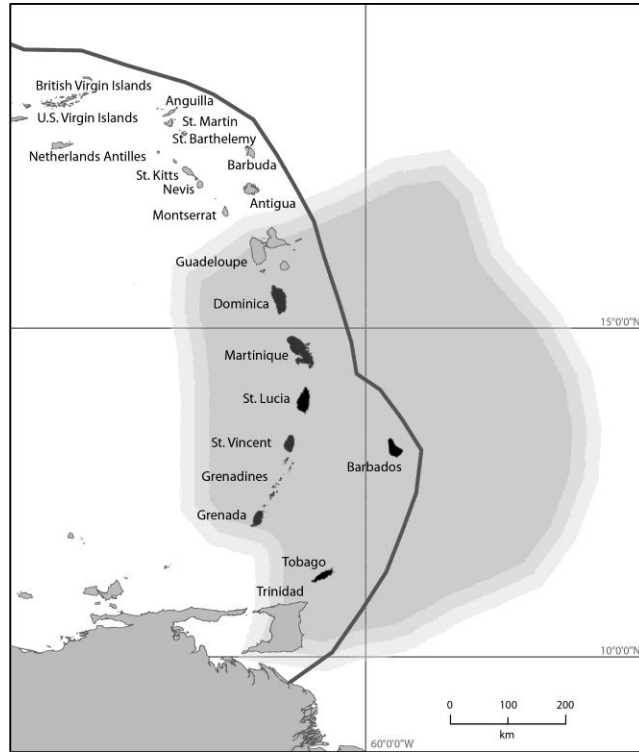


Figure 1: Map of eastern Caribbean countries with major fisheries for flyingfish (in dark grey). CLME boundary is represented, and approximate extent of area fished for flyingfish relevant to this project is shaded in grey. Distribution modified from Oxenford *et al.* (1995). Map by A.K. DeGraff.

It is widely recognized that the above fishery characteristics lend themselves to adopting a more holistic, ecosystem-based, approach to fisheries management for flyingfish fisheries (FAO 2002, 2003; Garcia *et al.* 2003; Grant 2008; Fanning and Oxenford 2009; Fanning *et al.* 2011). Such an approach, also referred to as an Ecosystem Approach to Fisheries (EAF), considers flyingfish fisheries as part of a complex and dynamic arrangement of interconnected human interactions and environmental linkages within an ecologically-driven system.

An effective EAF builds upon existing conventional management frameworks by strengthening the ecological context of decision-making, considering multiple societal objectives across many time horizons, and embracing uncertainty and change (FAO 2003; Garcia *et al.* 2003; Garcia and Cochrane 2005). It also places a strong emphasis on stakeholder engagement and participation in decision-making processes throughout the policy development cycle (Figure 2) (Grant 2008). This increase in stakeholder engagement encourages the formation of functional partnerships within and between multiple levels of governance, generally defined as the processes by which decisions are made and implemented, including formal and informal actors and structures (UNESCAP 2012). It also ensures the compatibility of defined management objectives with local needs and interests, improves the availability of information for decision-making, and strengthens the overall capacity of the region (Soma 2003; Grant and Berkes 2004).

In seeking to include a broader range of social, economic, and ecological considerations into a more holistic fishery assessment, however, an additional challenge arises. Given the often limited financial, institutional, and information resources available to tackle this increased level of management complexity how can decision-makers effectively incorporate multiple stakeholders with varying degrees of power and influence into the policy process and translate their multiple, often competing, objectives into meaningful and effective actions?

One tool that can be used to clarify desired priorities and increase the capacity for stakeholder participation and input is the multi-purpose Multi-Criteria Analysis (MCA). More commonly applied in terrestrial or business environments, the adaptable MCA framework (Figure 3) has gained recent popularity in marine and fisheries decision-making (e.g. Leung *et al.* 1998; Mardle and Pascoe 1999). This is because the MCA framework is capable of explicitly representing human values and preferences. It can provide a consistent structure by which to organize, analyse, and summarize the status of multiple objectives in relation to a range of management options or an overarching goal or vision (Leung *et al.* 1998; Fernandes *et al.* 1999; Mardle and Pascoe 1999; Mendoza *et al.* 1999). The MCA's robust yet flexible design is also capable of incorporating highly valued but complex and subjective management concepts such as 'sustainability' into its analysis framework.

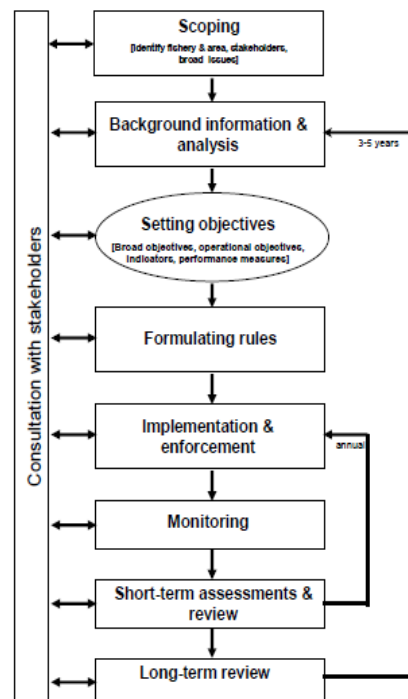


Figure 2: Steps in an Ecosystem Approach to Fisheries management plan (FAO 2003, In Grant 2008).

A complementary tool that can assist with the identification, structuring, and prioritization of management objectives in the MCA process is an Analytical Hierarchy Process (AHP) (Saaty 1980). Applied to a wide variety of problems in a diverse fields including environmental planning (Mardle and Pascoe 1999; Schmoldt *et al.* 2001), this process clarifies the structure and linkages of a particular issue by arranging its goal and associated elements into a hierarchy. The process then applies pairwise comparisons between these elements at each level to systematically determine the priority with which each of these elements is weighted in relation to each other (Schmoldt *et al.* 2001).

In the pursuit of proactive solutions to current fisheries management issues, the present study of both the overarching MCA framework and the complementary AHP undertaken investigates one component of a much broader marine resource management challenge: to find systematic, transparent, and participatory means by which multiple and competing objectives for Caribbean fisheries management can be more easily prioritized and desired options for action clarified and facilitated through increased stakeholder engagement. The study also considers the need to improve and expand the data and information required to support more holistic ecosystem-based decision-making for the eastern Caribbean flyingfish fishery.

## 1.2 An evaluation of MCA as a decision and information tool for flyingfish fisheries in the Eastern Caribbean

This Study was led by the Caribbean Regional Fisheries Mechanism (CRFM) under the auspices of the CLME project, with implementation and analysis support provided by two Canadian International Development Agency (CIDA) interns, Ms. Elaine Ferrier and Ms. Brooke Campbell. The CIDA internship arrangement was facilitated by the Dalhousie University Marine Affairs Program. Project activities were therefore carried out over two six-month phases in 2011. The following sections provide an overview of the activities undertaken in each phase.

### 1.2.1 Phase one - summary of activities

Phase one activities were conducted by during January to June 2011 (Ferrier and Singh-Renton 2012). Ferrier and Singh-Renton (2012) conducted a scoping study of the eastern Caribbean flyingfish fishery and its management, the identification of key stakeholders and critical issues, and the identification and an inventory of statistical information for the fishery. In reviewing the assessment literature the MCA and supporting AHP were identified as candidate tools for exploring and prioritizing management objectives and information needs for the flyingfish fishery. The methodology for the analysis was developed during this phase, with an emphasis on methods to hierarchically organize and prioritize the relative importance of objectives based on stakeholder input. A presentation of this methodology and a preliminary hierarchy of priorities were presented to experts for evaluation and feedback, with recommendations generated for phase two (CRFM 2011). For comparative purposes, key findings generated in phase one are also synthesized into the results and discussion of this report.

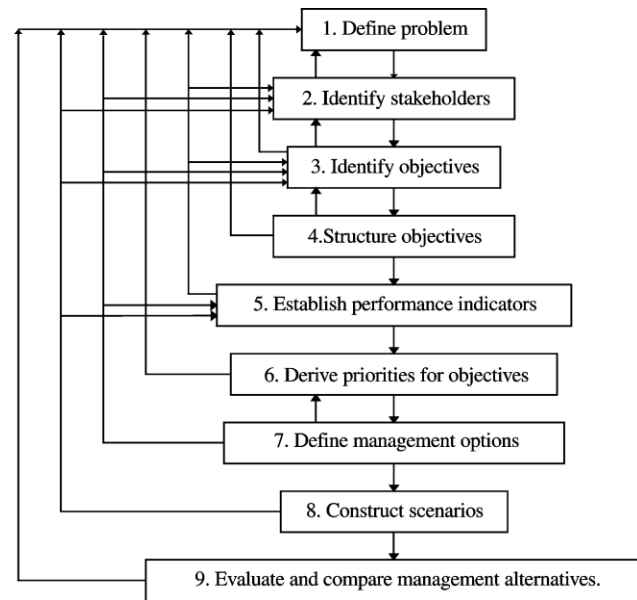


Figure 3: Steps involved in a Multi Criteria Analysis (in Fernandes *et al.* 1999).



### 1.2.2 Phase two - summary of activities

The second phase of the project was undertaken during June to December, 2011 (this report). Phase two activities strengthened and expanded upon the stakeholder input elicited for the prioritization of operational objectives within the existing Multiple Criteria Analysis (MCA) developed by Ferrier and Singh-Renton (2012). Additional phase two objectives included:

1. Understand the expectation of how the flyingfish fishery management objectives identified and prioritized during the entire study can become operational.
2. Identify, compile, verify, and hierarchically organize the information necessary to generate indicators and metrics of performance for the prioritized regional management objectives.
3. Continue to explore the functionality of a MCA to develop recommendations for the performance of priority management objectives identified by stakeholders and on the data and information base required to support an ecosystem-based approach to the management of the eastern Caribbean flyingfish fishery.

## **2. METHODS**

The methodology involved three key activity steps, undertaken in two phases:

1. The development of an MCA framework supported by Analytic Hierarchy Processes (AHP) to identify, organize, and prioritize management and information elements within the eastern Caribbean flyingfish fishery (primarily phase one);
2. The organization and implementation of field work to support MCA elements (phase one and two); and
3. The integration of these data into the developed MCA framework for analysis of outputs and the generation of recommendations (phase one (interim) and phase two (final)).

Ferrier and Singh-Renton (2012) describe the methods applied in the study's first phase and the MCA tool.

### **2.1 MCA framework development**

MCA framework development was primarily undertaken during the project's first phase. Minor adjustments have been made in the second phase following expert review and consultation. In developing a suitable framework, one of the advantages of the MCA is its flexibility of design while simultaneously observing a consistent progression of steps and a standard policy language (see Figure 3) (Fernandes *et al.* 1999; Mendoza *et al.* 1999). For clarity of interpretation, the standard policy language used in this report is defined here (modified from Mendoza *et al.* 1999):

- A *vision* is defined as a broad and general overarching intention with an intangible quality that provides the context for the overall project focus, in this case a fishery.
- An *objective* provides a framework and justification as well as a guiding principle for action towards the accomplishment of the overarching goal or vision.
- A *criterion* is a standard by which an objective is judged, adding meaning and operability to an objective without being a direct measure of performance. Also referred to as an *operational objective*.
- An *indicator* is a variable or component used to infer the status of a particular criterion and convey a single meaningful message.
- A *stakeholder* is a person, group or organization with an interest in the fishery and who affect or are affected by fishery management actions.

The general MCA framework shown in Figure 3 is slightly modified for our study (Table 1). MCA decision elements specific to flyingfish (i.e. flyingfish fishery goals, objectives, criteria, indicators) were derived by both synthesizing available fisheries literature and by soliciting expert opinion (Table 1: Steps

1-4). There are, however, a number of ways in which Steps 1-4 may be achieved, including through in-depth stakeholder consultation.

Reference sources for the flyingfish fishery goals, objectives, and criteria include but are not limited to those identified in WECAFC (2008, 2010), national FMPs and national reports submitted to CRFM annual scientific meetings. As the focus of this study is to undertake activities which support an ecosystem approach to fisheries management, these management decision elements are deliberately regional in scale and are therefore designed to have cross-cutting themes. Steps 1 to 3, 5, and 6 were developed in detail in phase one of the project (Ferrier and Singh-Renton 2012), while Steps 4 to 7 were developed in the second phase (this paper). Due to a range of limitations noted in our the discussion, the completion of Steps 7 through 10, or the evaluation of management objective performance in relation to the overarching criteria and vision, was not possible during phase two.

*Table 1: General steps taken in the Multi-Criteria Analysis for eastern Caribbean flyingfish. Adapted from Ferrier and Singh-Renton (2012) and based primarily on Jennings (2005) and Fernandes et al. (1999).*

	<b>MCA Steps</b>	<b>Methods applied within MCA</b>
1.	Define the issue - includes identifying stakeholders and overarching goal or vision	<b>Literature Review and expert consultation</b>  (WECAFC 2008, 2010; FMPs, national reports submitted to the CRFM)
2.	Identify objectives to satisfying the goal.	
3.	Identify criteria to satisfy the objectives.	
4.	Identify indicators to illustrate performance of each criterion in relation to satisfying the objectives.	
5.	Organize the identified objectives, criteria and indicators into an assessment framework or hierarchy.	<b><u>Analytic Hierarchy Process (AHP)</u></b> <b>Static organizational hierarchy</b> (Schmoldt et al. 2001)
6.	Derive priorities for objectives: determine the weighting (relative importance) of each objective and/or criteria relative to the overall goal.	<b>Simos' Pack of Cards</b> (Simos in Ondrus and Pigneur 2006) <i>Objectives and Criteria only</i> <b><u>AHP</u></b> <b>Modified Pairwise comparison</b> <b>Averaging judgments (geometric mean)</b> (Saaty 1980; Schmoldt et al. 2001)
7.	Develop indicator scoring index and score indicator performance.	<b>Normalized ordinal scale</b>
8.	Multiply performance of indicators for each criteria or objective by the relative importance weighting of that criteria or objective.	
9.	Define management priorities: represent these final scores in the hierarchy to demonstrate how well each objective and/or criteria are performing in relation to the goal or vision.	
10.	Re-evaluate goals and objectives based on outcomes and refine if necessary.	

### 2.1.1 Identification of indicators

In Table 1: Step 4, the identification of relevant indicators to assess the performance of each eastern Caribbean flyingfish fishery criterion in relation to their associated objectives required the development of a more in-depth methodology; this was developed in phase two. Because of their ability to summarize large quantities of complex information, indicators play a key role in clarifying and improving the communication of scientific results to decision-makers (Jennings 2005). However, because they are a simplifying tool for large and complex systems, their appropriate selection must be carefully considered

in order to remain relevant, representative, and practical (FAO 1999). Jennings' (2005) process for selecting indicators to support an Ecosystem Approach to Fisheries (EAF) was simplified for the smaller scope of this study and is represented in Table 2.

1.	Referring to criteria and objectives compiled from the national and regional management literature, compile a broad list of candidate indicators for the fishery from the literature.
2.	Referring to these same criteria and objectives, identify the fishing impacts that may compromise each operational objective (based on past and present experience and expectations for the future).
3.	Consider how likely (from high to low probability) it is that these fishing impacts will compromise the achievement of objectives.
4.	Define criteria for indicator selection: SMART, Pressure-State-Response (PSR) etc.
5.	Based on Steps 2-4, identify candidate state indicators for fishing impacts most likely to compromise each objective. Specificity, complexity, and number of indicators selected will reflect resources available for management.
6.	Identify potential pressure and response indicators to describe the pressures and management responses that influence the value of each state indicator.
7.	Refine the list of candidate indicators based on the availability of current data and information to identify/develop reference points, direction or trajectory for each state, pressure, and response indicator. Determine response times to specified changes in true values.

The purpose of using indicators in this study is to measure and review management objective performance; as such, selected indicators take on an 'audit' rather than a 'control' function. A commonly-applied indicator framework discussed in the literature and used in this assessment is the Pressure-State-Response (PSR) framework. State indicators advise on the state of an ecosystem, its component elements and traits, and the extent to which related management objectives are being met. An ecosystem's state is only effectively managed (and associated management objectives effectively achieved) when the relationships with pressure factors (in this case fishing) and management responses are identified (Jennings 2005). Ideally, each indicator type is represented within a well-rounded indicator framework. In order for indicators to better fulfil their role of informing people about complex systems and their relationship to management in a meaningful way they should also be accessible, easily understood, and generally accepted by stakeholders as relevant to the issue in question. In this regard "SMART" principles: Specific, Measurable, Achievable, Realistic, and Timely, were relied upon to inform indicator selection (Doran 1981).

The indicator selection criteria developed for this evaluation relied on a synthesis of ideas from the literature (FAO 1999, ESD 2002, Legallic 2002, Degnbol 2004, Jennings 2005, Grant 2008). The most notably referred-to data and information base used to compile the preliminary list of candidate indicators for this were FAO (2008, 1999), IUCN (2004), ESD (2003), and Shin *et al.* (2010). The data and information base used to refine the indicator list more specifically for flyingfish fishery management, including reference points, consisted of annual national reports, industry reports, consultations with experts, and the information provided by WECAFC (2010).

### 2.1.2 The Analytic Hierarchy Process

Once criteria and objectives are identified and indicators are selected, the next step in the MCA framework is to arrange all of these assessment elements into a relevant and meaningful format. This facilitates the clarity and transparency of process and analysis and better identifies and defines linkages between elements. Hierarchy trees are a common conceptual tool used in decision analysis to clarify the linkages between management decision elements. They are also a main component of an Analytic Hierarchy Process (AHP), a structured method for organizing and analyzing complex decisions, with applications in a range of different fields from health care to business and to education (Saaty 1980;

Schmoldt *et al.* 2001). There are a range of hierarchical structures which can be applied depending on the linkages in the system you wish to represent (Schmoldt *et al.* 2001). One of the more common hierarchical structures applied in decision analysis is the Static Hierarchy (see Fletcher *et al.* 2002; Grant 2008). This simple hierarchy uniformly arranges layer elements *a priori*. This allows for a greater focus on pairwise comparisons, a process which allows for a large number of participants to provide their input on the formalization of comparison steps through the use of a survey instrument (Schmoldt *et al.* 2001). For these reasons, a static hierarchy was applied in this analysis.

In referring to this hierarchy, it should be noted that the phrasing of the objective categories has been modified slightly from the first phase to align more closely with the Australian Ecologically Sustainable Development (ESD) reporting process. The ESD is a management decision analysis framework with a complementary structure and overarching purpose that is used to analyse performance and risk in Australian fisheries management actions (Fletcher *et al.* 2002). This modification introduces the theme of system 'well-being', defined broadly in this sense to mean a system that focuses on being well in health, happiness, prosperity, an ability to be productive and engaging, and to cope with and respond positively to difficult circumstances. The organized *a priori* hierarchy of elements specific to this analysis, including preliminary criterion indicators, is represented in Figure 4.

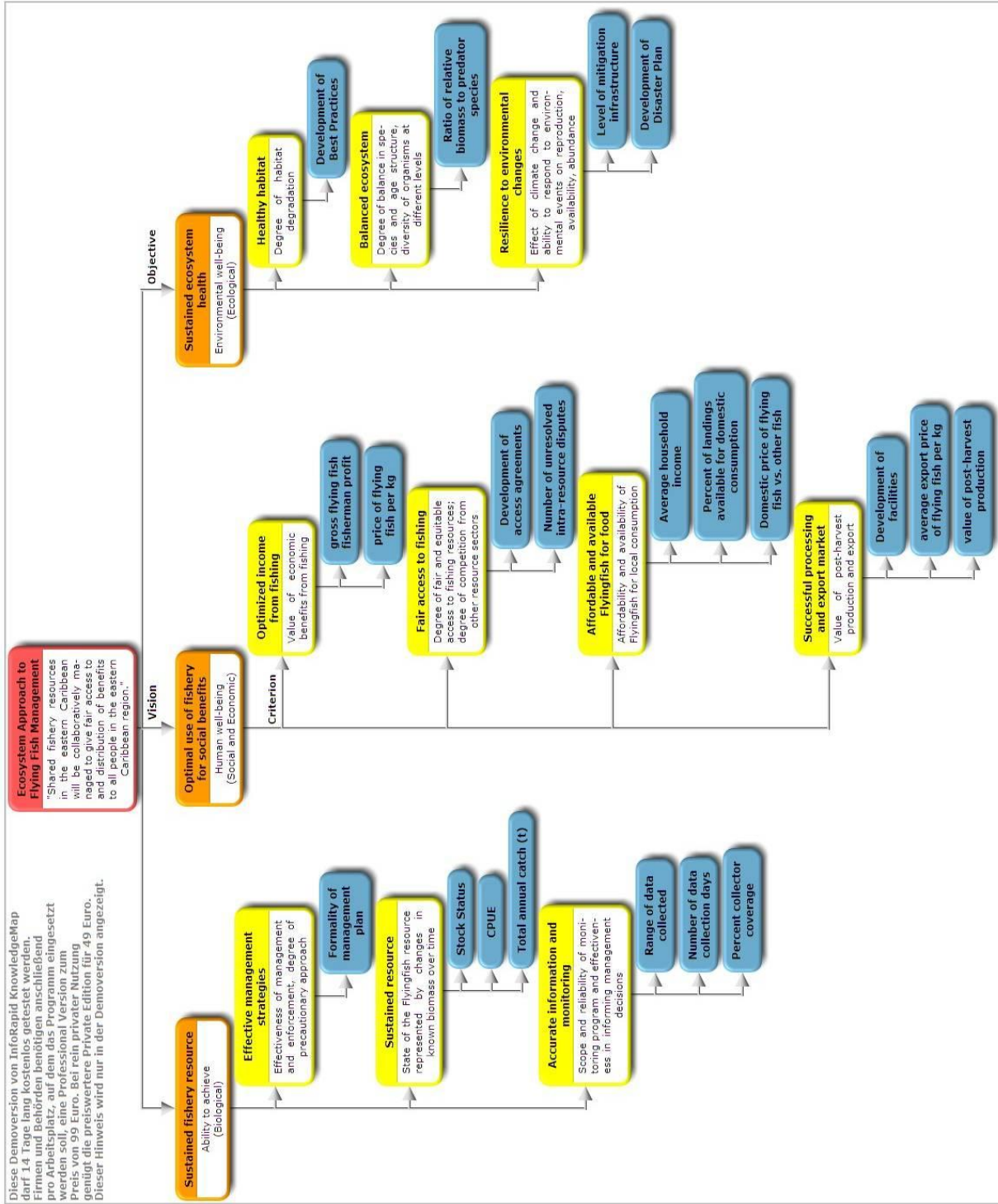


Figure 4: Static hierarchy of regional-scale eastern Caribbean flyingfish fishery management plan elements. All hierarchy elements are synthesized from the literature. Preliminary 'Best Available' criterion indicators are included to further illustrate the hierarchy process. Criterion and indicator layer elements are arranged lengthwise but are not ranked in order of importance.

## 2.2 Field research design for management objective prioritization

Once the hierarchy of management plan elements is arranged, the next step in the MCA is to derive priorities for layer elements and to relate these priorities back to the overarching management goal or vision (Table 1: Step 6). This prioritization of management criteria and objectives helps to clarify potential priority areas of focus in management plans which include multiple and often conflicting objectives. This clarification in turn can also help facilitate the operationalization of management elements. By engaging stakeholders in this aspect of the policy development cycle, management objectives will more strongly reflect stakeholder needs. AHP was again applied to facilitate this prioritization, using a modified pairwise comparison process by way of a survey instrument (Schmoltdt *et al.* 2001). Stakeholder input was directly solicited for criterion comparisons vis-à-vis their relative importance for management, as perceived and prioritized by each surveyed individual. Input was also sought for informing management objective operationalization strategies, identifying metrics of performance and success for management plan elements, and identifying strengths and weaknesses in data and information. The following section addresses the methodology of the survey instrument and the supporting field research.

### 2.2.1 Study population

While a full assessment of the flyingfish fishery should include representation and input from all identified major stakeholders, a target population of representative primary stakeholders was selected for the purposes of this study, and is described in Table 3. Of note is the exclusion of vendors working for companies who sell flyingfish wholesale or for export.

*Table 3: Selected study population of the eastern Caribbean flyingfish MCA assessment.*

Category	Role	Description
Primary industry	Fisherman / Fisherwoman Boat owner / Captain / Crew	Persons who during the season self-identify as active fishers of flyingfish, as either a target or non-target species, primarily for human consumption (i.e., may include some fishing for bait)
Secondary industry	Processors Processor owners Small-scale Vendors / Hawkers	Persons who prepare flyingfish for sale (including boning, scaling, filleting) and/or who are directly involved in the sale of flyingfish to individual consumers in the market
Administration	Department heads Fisheries officers Database personnel Resource managers Fisherfolk organization heads	Persons directly involved in the management, coordination, and data collection of the flyingfish fishery and related information
Research	Academic experts	Persons directly involved in the research and analysis of flyingfish fisheries and related information

At the time that fieldwork was undertaken, uncertainty in the reliability of the total reported population of individuals involved specifically (but not exclusively) in the flyingfish fishery both nationally and by landing site (as an example see Staskiewicz *et al.* 2008), meant that it was problematic to calculate an appropriate stakeholder survey sample size based on total population. As a result, sampling focused on being representative of the reported proportion of stakeholders by category, as well as on maximizing geographic sampling coverage (i.e. as much as possible, sampling from as many landing sites identified as important for flyingfish in each study country).

### 2.2.2 Sampling location

Sampling of primary stakeholders took place at individual landing sites and at fisheries offices around Barbados, Tobago, and St. Lucia, over a one year period (2011) and one flyingfish fishery season (November-June). These three eastern Caribbean countries represent a range of capacity and mechanization in flyingfish fishery development, with Barbados catching the majority (~50%) of the region's flyingfish for consumption (WECAFC 2010). Barbados was sampled twice: once during the flyingfish fishery peak season (May 2011), and once during the off-season (August 2011). Tobago was also sampled both during the peak and off seasons for fishing (May 2011 and August 2011, respectively). St. Lucia was sampled once during the off-season (October 2011).

Major landing sites for flyingfish were targeted for sampling in each country; these were identified with the assistance of national fisheries staff and include primary, secondary, or tertiary landing sites (which are distinguished primarily by the level of fishing activity and infrastructure development). An effort was made to sample as widely as possible within each country; however, as the purpose of site visits was to obtain the largest sample of individuals possible and the selection of sampling locations was limited by time and logistical constraints, the largest and most easily accessible landing sites were the most strongly represented in each country (Figures 5, 6, and 7).

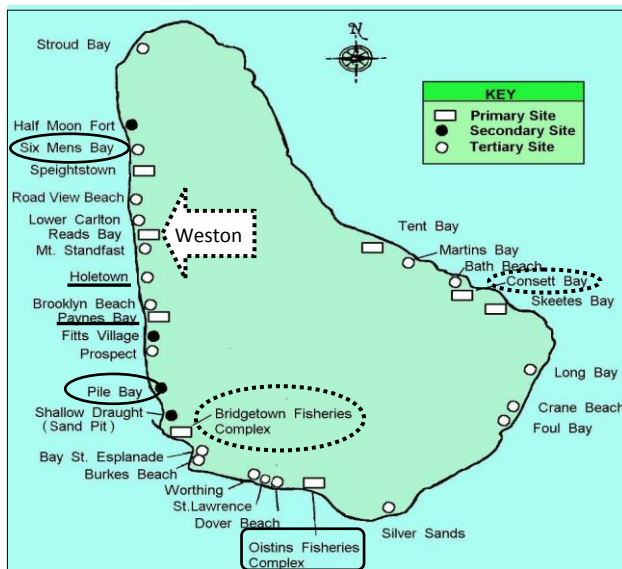


Figure 5: Map of landing sites visited in Barbados. Grey square, black, and dashed circles represent sites sampled in phase one, phase two, and in both phases, respectively. Holletown and Paynes Bay landing sites (underlined) were visited in phase 2; however, no surveys were possible. Image source: T. Hamilton and Associates (2009a).

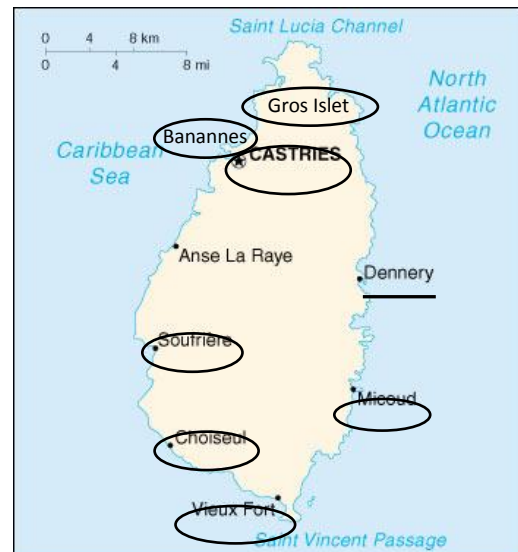


Figure 6: Map of landing sites visited in Saint Lucia in phase two only. A site visit to Dennerly (underlined) obtained no interviews and was identified by Saint Lucia Department of Fisheries as having a low importance for flyingfish landings. Image source: Modified from FAO (2012).

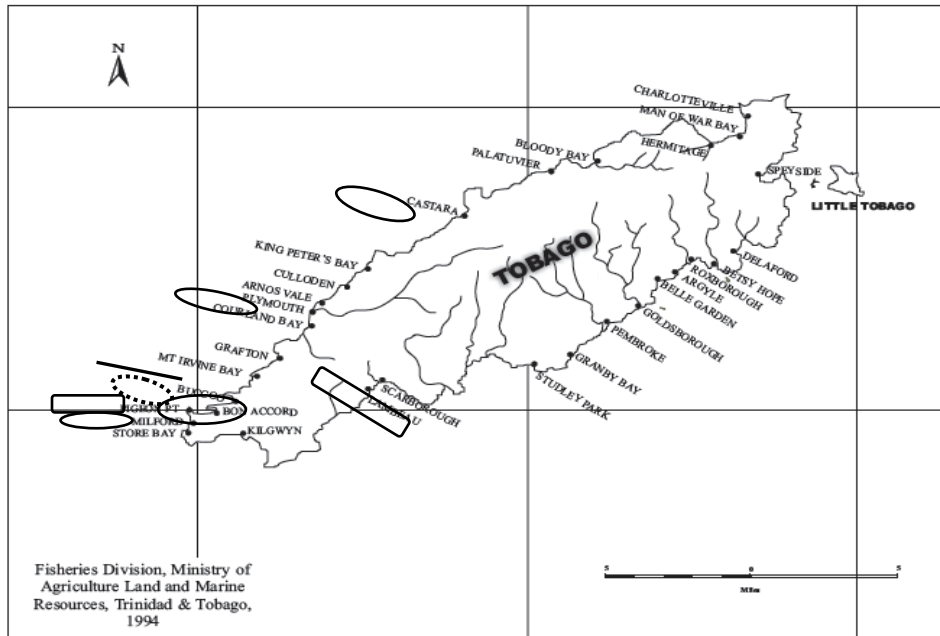


Figure 7: Map of landing sites visited in Tobago. Grey square, black, and dashed circles represent sites sampled in phase one, phase two, and in both phases, respectively. Pigeon Point, Scarborough, and Mt. Irvine were also visited in Phase 2; however, no surveys were possible. Sampling of Eastern landing sites was not identified as a priority for flyingfish by Tobago Fisheries Division staff. Image source: MALM (1994) in T. Hamilton and Associates (2009b).

### 2.2.3 Field data collection

Data collection at the landing sites in both phase 1 and phase 2 focused on eliciting stakeholder valuation and prioritization of the operational flyingfish fishery management objectives (i.e. criteria) synthesized from the literature beforehand. Stakeholder input on prioritization was elicited by conducting voluntary individual surveys of the sample population of primary stakeholders defined in section 2.2.1. These prioritizations were then used to inform the weighting of hierarchically arranged management criteria and objective elements. Secondary data, including additional stakeholder values, concerns, feedback, and linkages were also collected during the survey process. These data were recorded in relation to each respective criterion so as to facilitate the coding of qualitative data, to augment the survey response information; this provides a rationale for responses, and hence for priority areas for action and information improvement. The survey methodology was initially developed and tested in phase 1, and so is fully described in Ferrier and Singh-Renton (2012).

At the departmental offices of each country, as well as at the Centre for Resource Management and Environmental Studies (CERMES) at the University of the West Indies (UWI) campus in Barbados, data and information collection focused on eliciting individual primary stakeholder input with regard to measurably evaluating the performance and effective operationalization of flyingfish fishery management objectives. Only research and administration stakeholders were targeted for this particular input. This input was used to inform the selection and development of the preliminary MCA assessment indicators. Where possible, data and information sources were identified and recorded for future indicator development. These data include socio-economic, biological, and governance data, as well as baseline, target or limit reference points. Input from Mr. Chris Parker at the Barbados Fisheries Division, Dr. Robin Mahon and Dr. Patrick McConney at CERMES, as well as Mr. Garth Ottley from Tobago Marine Resources and Fisheries Department were particularly useful and appreciated.



**2.2.4 Field data collection instrument**

A non-probability sampling methodology - a stratified convenience sample of individuals at landing sites and in departmental offices, was determined to be the most practical means of sampling flyingfish fishery stakeholders in the most representative manner possible, while accounting for time and other logistical constraints, and the exploratory nature of the study. Data and information on stakeholder values and the priority ranking of flyingfish fishery management criteria were collected in a voluntary semi-structured interview for each sampled stakeholder for as many stakeholders as possible. Taking into account the limitations of a long-form survey methodology on the availability and willingness of stakeholders to participate in the field, the survey instrument employed an interactive “pack of cards” technique, developed by Simos (1990) and described in Ondrus and Pigneur (2006). For the pack of cards exercise, each of the ten flyingfish fishery management criteria synthesized from the literature in phase one were represented on an individual card, along with a short descriptive phrase and an image illustrating the criterion concept (Ferrier and Singh-Renton 2012). The criteria are listed in Table 4.

*Table 4: Flyingfish fishery management criteria (ie. operational objectives) represented on the ten interview cards for the survey ‘pack of cards’ exercise (criteria in parentheses if abbrev. on the cards).*

<b>Theme and Objective</b>	<b>Interview Card Number</b>	<b>Criterion</b>
<b><u>Ability to achieve (Biological Theme)</u></b> Objective: Sustained fishery resource	1.	Sustained resource
	2.	Accurate information and monitoring (Accurate information)
	3.	Effective management strategies (Effective management)
<b><u>Human well-being (Social and Economic Theme)</u></b> Objective: Optimal use of fishery for social benefits	4.	Optimized income from fishing (High profits)
	5.	Fair access to fishing
	6.	Affordable and available flyingfish for food (Affordable food source)
	7.	Successful processing and export market
<b><u>Environmental well-being (Ecological Theme)</u></b> Objective: Sustained ecosystem health	8.	Healthy Habitat
	9.	Balanced ecosystem
	10.	Resilience to environmental change

Prior to conducting the field interviews, a brief explanation of each of the concepts represented on each card was presented at the beginning of the pack of cards exercise, and any terminology or conceptual questions were clarified. Survey respondents were then asked to arrange the criterion cards in ordinal importance (i.e. from most to least important) based on how they would personally prioritize the management criteria (Figure 8). A respondent was permitted to rank a criterion as equally important to another, or as not important at all (i.e., as opposed to ‘least important’). If a respondent identified a management criterion as not important to them, they were asked to provide a rationale. This secondary information not only strengthened the context of the response, it provided an opportunity to identify potential misunderstanding with respect to the card concepts.

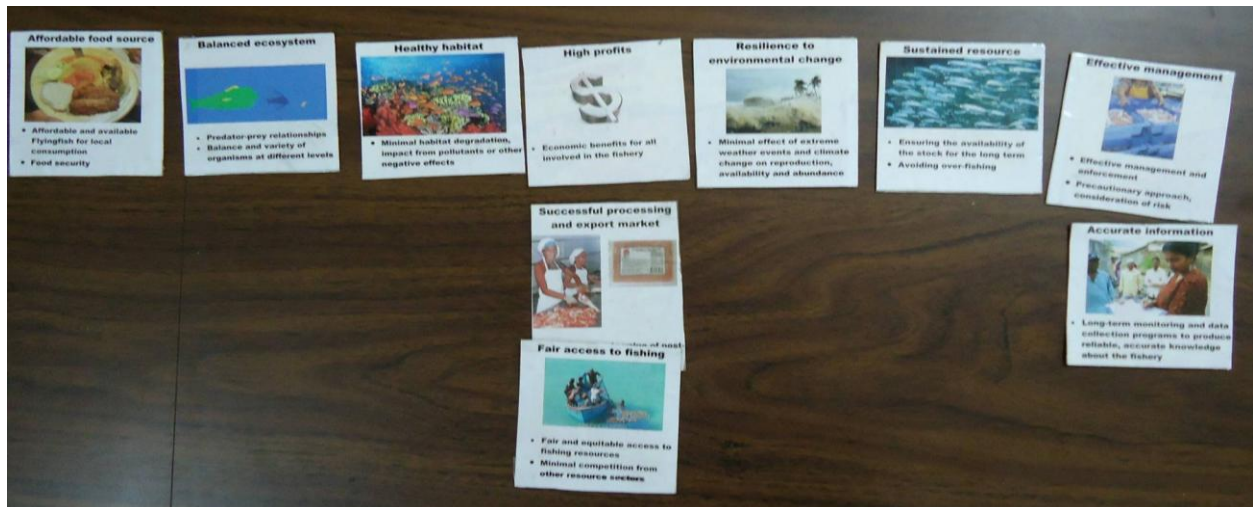


Figure 8: A visual demonstration of Simos' (1990) "pack of cards" method as it might appear after flyingfish fishery management criteria are arranged in order of most to least important (from left to right) by a surveyed stakeholder. In this example, some criteria have been assigned the same level of importance.

### 2.3 Multi-Criteria Analysis Assessment

The ordinal survey responses were recorded for each respondent and then converted into a numeric format using the AHP's modified pairwise comparison process in order to obtain criteria weights and ranking. The modified pairwise comparison assumes that the ordinal ranking of each criterion card in relation to the other implies that the respondent believes a criterion to be more, less, or equally as important as the criterion on the card placed below, above, or at the same level with it, respectively. The pairwise comparison applied in this evaluation is modified from a full AHP pairwise (see example in Leung *et al.* 1998), in order to simplify and facilitate its use in the field, as described by Ferrier and Singh-Renton (2012). The calculation of weights from this comparison exercise is described in the following section.

#### 2.3.1 Weighting of management criteria and objectives

To obtain the weighted hierarchy of prioritized criteria and objectives, the modified pairwise responses for each interviewed stakeholder were first tallied for each respondent individually. Each criterion was assigned a 'score' based on how the respondent prioritized it within the total hierarchy. A criterion was assigned a score of 1 in the pairwise comparison if it was ranked by the respondent as more important than another criterion, and a 0 if it was ranked as less important. Therefore if a respondent ranks all 10 criteria from 1 to 10 then the most important criterion in that arrangement achieves an individual total 'score' of 10, while the least important criterion achieves a 'score' of 1 (Figure 9). This methodology is modified slightly from phase one, where the least important criterion was assigned a score of 0. This modification reflects the difference between not ranking a criterion as important at all (here referred to as a "null score" or "null response") and ranking it as the least important in a series.

Rank	3: B-BT2	Sustainable resource	Information and monitoring	Management	Profits	Fisheries	Food	Processing and export	Habitat	Species structure	Resilience	NULL	Total Score	Weight
2	Sustainable resource		0	1	1	1	1	1	1	1	1	1	9	16%
1	Information and monitoring	1		1	1	1	1	1	1	1	1	1	10	18%
3	Management	0	0		1	1	1	1	1	1	1	1	8	15%
4	Profits	0	0	0		1	1	1	1	1	1	1	7	13%
6	Fisheries	0	0	0	0		1	1	0	1	1	1	5	9%
9	Food	0	0	0	0	0		0	0	1	0	1	2	4%
8	Processing and export	0	0	0	0	0	1		0	1	0	1	3	5%
5	Habitat	0	0	0	0	1	1	1		1	1	1	6	11%
10	Species structure	0	0	0	0	0	0	0	0		0	1	1	2%
7	Resilience	0	0	0	0	0	1	1	0	1		1	4	7%
	NULL	0	0	0	0	0	0	0	0	0	0		0	0%
													55	100%

Figure 9: Example of a completed AHP modified pairwise comparison for a surveyed individual. The ‘null’ row and column was added in phase two. The criterion with the highest score, and therefore the greatest weight, is highlighted in yellow.

A respondent who ranks all 10 criteria from 1 to 10 has a combined total score of 55. For each respondent, the score for each criterion is then divided by the combined total score to determine its proportional weight. The weighting of each criterion is then summed across all interviewed respondents in each country, phase, and then overall. From this, an overall average weighting for each criterion is obtained. Total average criterion weights are summed again to obtain the relative weighting of each broader objective. Further explanations of the method applied are provided in Ferrier and Singh-Renton (2012).

### 2.3.2 Indicator scoring

A draft indicator scoring metric, with performance reference points ranked on a five-point Likert item scale, is proposed here but further conceptual development is required (Table 5). Each of these reference points represents a desired target or a limit state or direction for management action; these targets are then compared to some benchmark in time to obtain a score. As these reference points indicate the performance of indicators with different units of measure, it is necessary to implement a normalized scoring index with one standard unit of measure. For example, the ‘total annual catch’ indicator of the *Sustained Resource* criterion could be matched against the currently proposed Target and Limit Reference Points (TRP and LRP) in WECAFC (2010) as an indicator of criterion performance. The LRP for regional flyingfish catch is 5,000 mt total per year (WECAFC 2010); using the normalized scoring index below, this value would translate into a “Worst” indicator score, or a “1” performance assessment score. The current TRP is the same as the average annual regional production of 2,500 mt in 2007, a potential benchmark year (WECAFC 2010); as currently defined this catch level has a “Best” score, or a “5” performance assessment score.

*Table 5: Proposed draft indicator scoring index with normalized scale.*

	<b>Likert Item Scale</b>					
	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Performance assessment score</b>	Impossible to score at time of assessment	Very weak Very Unfavourable	Weak Unfavourable	Acceptable At or Above regional norm for 'good operations'	Strong Favourable Well Above regional norm	'State of the art' Outstanding relative to regional norm
<b>Type of indicator information and associated score</b>						
<b>Reference Points</b>	None Available	Worst (Limit)		Moderate		Best (Target)
<b>Policy Documentation</b>	None	Written mention	Draft	Final Version	Implemented	Actions Reviewed and/or Revised
<b>Presence/Absence</b>	Unknown	No		Partial		Yes
<b>Abundance</b>	Unknown	None		Some		All
<b>Completeness of data</b>	None	Catch only	Catch, Effort	Catch, Effort, Most Biological, Some Economic	Catch, Effort, Biological, Most Economic, Some Social	Catch, Effort, Biological, Economic, Social, Ecological
<b>Proportion (%)</b>	0	10	25	50	75	100
<b>Value</b>	0	10	25	50	75	100

Once these normalized performance scores are derived for each indicator, they can be multiplied by their associated criterion weights in order to obtain the weighted and scored management objective outcome in the MCA assessment (Table 1: Step 8 and 9). These numeric outcomes can then be used to demonstrate how well management objectives and criteria are performing in relation to the overall management plan goal or vision. It also provides an opportunity to re-evaluate current goals and objectives based on these outcomes and to refine these if necessary based on increased stakeholder input. Finally, these scores can also point to strengths and weaknesses in policy cycle linkages and information. An alternate method for incorporating indicators into an MCA includes a prioritized weighting of indicators as well as criteria (Mendoza *et al.* 1999), but this was not undertaken in this analysis.

### 3. RESULTS

#### 3.1 Sampling coverage

##### 3.1.1 National coverage

A total of 114 primary stakeholders (phase one and two combined) from 20 different landing sites across Barbados, Saint Lucia, and Tobago were interviewed to obtain their opinions on the prioritization of flyingfish fishery management objectives (Table 6). During phase two sampling, a few fishermen in Barbados and Tobago identified as having already been sampled in phase one; however this number was not explicitly recorded.

Table 6: Total number of individuals sampled by country and stakeholder category in both Phases. Number of females sampled is in parentheses. \*See text for explanation of 0 in Saint Lucia sample. \*\*Total estimated population in flyingfish fisheries is from WECAFC (2010) – these estimates may include individuals who do not fish, process, or vend flyingfish or data may be out of date. Estimates are therefore included here only as a general proportional reference.

Country	Total Population Estimate** (# of individuals)		Survey Sample (# of individuals)			
	Primary	Secondary	Primary	Secondary	Admin	Country Total
<b>Barbados</b>	1100	450	32	15 (8)	5 (3)	<b>52</b>
<b>Tobago</b>	228	200	22	4 (1)	2 (1)	<b>28</b>
<b>Saint Lucia</b>	915	N/A	31	*0	3 (3)	<b>34</b>
<b>Total</b>	<b>2243</b>	<b>650</b>	<b>85</b>	<b>19</b>	<b>10</b>	<b>114</b>

The number of individuals interviewed was similar between the peak season (Phase 1) and off-season (phase 2) for fishing in Barbados (24 in phase one and 28 in phase two) and Tobago (13 in phase one and 15 in phase two). Saint Lucia was only sampled in phase two (34 individuals). In Saint Lucia, flyingfish fishermen identified themselves as the primary vendors of flyingfish and stated that most processing of flyingfish is done by individual consumers in the home; it is for this reason that the secondary industry sample is an empty set (n=0). With regard to the representativeness of the sample by gender, only Barbados has the resolution of data available for such an analysis. In the (female-dominated) processing and vending sector, Barbados estimates that women are on average 63.5% of this sector (Staskiewicz *et al.* 2008). At 8 out of the 15 people sampled in the secondary industry in Barbados, the female representation in the sampled population is therefore 53%. Gender demographics by sector for Tobago and Saint Lucia are either not available or are based on out-of-date estimates and are therefore not reliable for comparison. No female fishermen were interviewed in the three sampled countries; while they do exist they are not common.

### 3.1.2 Coverage by landing site

In Barbados, 6 out of a total 32 landing sites identified in the statistical reports of the Barbados Fisheries Division were sampled, for a 19% site sampling coverage (Table 7). All except one of the 6 sampled sites have regular data collector coverage. Holetown and Paynes Bay landing sites were also visited in Phase two; however, no interviews were conducted due a very low number of flyingfish fishers present and/or a lack of desire by the stakeholders to participate in the interview process. The Paynes Bay fish market was also temporarily closed at the time of the site visit. More so in Barbados than in the other two sampled countries, it should also be noted that the landing sites where the stakeholder were interviewed did not always correspond with where they land flyingfish, particularly when the interview took place in the off-season. Both interview site and landing site (if different) were recorded in the survey data.

Table 7: **Barbados** - Number of individuals sampled by landing site and sector in both Phases. Superscript numbers indicate if a landing site was primary, secondary, or tertiary.

Landing site	Survey sample (# persons)		
	Fisher	Processor/ Vendor	Admin
<b>Total sites: 32</b>			
Bridgetown <sup>1</sup>	11	11	5
Oistins <sup>1</sup>	3	1	0
Conset Bay <sup>1</sup>	12	0	0
Weston <sup>1</sup>	2	1	0
Six Mens Bay <sup>3</sup>	2	2	0
Pile Bay <sup>2</sup>	2	0	0
<b>Total: 52</b>	<b>32</b>	<b>15</b>	<b>5</b>

Table 8: **Tobago** - Number of individuals sampled by landing site and sector in both phases. Superscript numbers indicate if a landing site was primary, secondary, or tertiary.

Landing site	Survey sample (# persons)		
	Fisher	Processor/ Vendor	Admin
<b>Total sites: 31</b>			
Scarborough <sup>1</sup>	2	2	2
Buccoo <sup>2</sup>	9	0	0
Pigeon Point <sup>3</sup>	5	0	0
Milford Bay <sup>3</sup>	3	0	0
Bon Accord	0	2	0
Plymouth <sup>2</sup>	1	0	0
Castara <sup>2</sup>	2	0	0
<b>Total: 28</b>	<b>22</b>	<b>4</b>	<b>2</b>

In Tobago, 7 out of a total 31 landing sites identified in the statistical reports of the Tobago Department of Marine Resources and Fisheries were sampled, for an 18% site sampling coverage (Table 8). All 7 sampled sites have regular data collector coverage. Pigeon Point, Scarborough, and Mt. Irvine landing sites were also visited in Phase two; however, no interviews were conducted for the same reasons as in Barbados. Tobago Fisheries Division staff identified Eastern landing sites as insignificant contributors to flyingfish landings.

In Saint Lucia, 7 out of a total of 17 sites identified in the statistical reports of the Saint Lucia Department of Fisheries were sampled, for a 41% site sampling coverage (Table 9). Anse La Raye and Canaries were identified by Fisheries staff as important landing sites for flyingfish but were not visited due to logistical constraints.

Table 9: **Saint Lucia** - Number of individuals sampled by landing site and sector in Phase 2. Superscript numbers indicate if a landing site was primary, secondary, or tertiary.

Landing site	Survey sample (# persons)		
	Fisher	Processor/ Vendor	Admin
<b>Total sites: 17</b>			
Gros Islet <sup>1</sup>	3	0	0
Castries <sup>1</sup>	3	0	1
Banannes <sup>3</sup>	2	0	0
Soufriere <sup>2</sup>	10	0	1
Choiseul <sup>2</sup>	4	0	0
Vieux Fort <sup>1</sup>	1	0	0
Micoud <sup>2</sup>	8	0	1
<b>Total: 34</b>	<b>31</b>	<b>0</b>	<b>3</b>

All 7 sampled sites have regular data collector coverage. Dennery landing site was also visited but no interviews were obtained; however it was not identified as a priority site for flyingfish landings by accompanying Fisheries Division Staff.

### 3.2 Stakeholder weighting and prioritization of management elements

#### 3.2.1 Management objective hierarchy

The weighted management criteria and objectives below, derived from the stakeholder interview pairwise comparison scores, represent the average relative importance of a management criterion for each stakeholder, out of a total of 100% (Table 10). For example: the criterion *Sustained resource* has

the strongest combined overall weighting at 13.3%. It is therefore the criterion given the highest overall relative importance when all three countries and all 114 stakeholders are analysed together. This means that the desire for a *Sustained resource* can be interpreted as a top priority for flyingfish fisheries management.

Of the three eastern Caribbean countries included in this assessment, the biological ‘Ability to achieve’ management objective Sustained Fishery Resource is identified by flyingfish fishery stakeholders as their

top priority management objective. However, the socio-economic ‘Human well-being’ objective Optimal Use of Fishery for Social Benefits was weighted so similarly that both objectives could be effectively considered to be of equal importance to stakeholders. The *Effective Management* criterion is also weighted in the top three by each sampled country. The highest priority management criterion identified as desirable in Barbados, Tobago, and Saint Lucia respectively is *Sustained Resource*, *Sustained Resource*, and *Accurate Information and Monitoring*.

*Table 10: Average weighting of operational management criteria for each sampled country and combined from both project phases (expressed as a percentage). The top 5 priority objectives, with the strongest weights, are represented in bold. Weighting for each objective is represented in parentheses. Weightings are based on the ‘pack of cards’ responses and pairwise comparisons. \*While the description of the concept to stakeholders remained the same between phases, some ambiguity may exist in the language between phase 1 and 2 reports.*

<b>Operational management objective (i.e., criterion)</b>	<b>Ran k</b>	<b>Combined N=114</b>	<b>Barbados N=52</b>	<b>Tobago N=28</b>	<b>Saint Lucia N=34</b>
<b>Ability to achieve objective: Sustained fishery resource (38%)</b>					
Sustained resource	<b>1</b>	<b>13.3</b>	<b>14.1</b>	<b>16.2</b>	9.8
Accurate information and monitoring	<b>4</b>	<b>11.5</b>	<b>10.5</b>	<b>9.4</b>	<b>15.0</b>
Effective management strategies	<b>2</b>	<b>13.0</b>	<b>11.4</b>	<b>15.0</b>	<b>13.8</b>
<b>Human well-being objective: Optimal use of fishery for social benefits (37.5%)</b>					
Optimized income from fishing	<b>5</b>	<b>10.4</b>	10.2	8.8	<b>12.0</b>
Fair access to fishing	<b>9</b>	7.4	8.3	<b>8.9</b>	4.7
Affordable and available flyingfish for food	<b>8</b>	7.5	6.7	7.6	8.8
Successful processing and export market	<b>3</b>	<b>12.1</b>	<b>10.4</b>	<b>15.8</b>	<b>11.7</b>
<b>Ecological well-being objective: Sustained ecosystem health (24.5%)</b>					
Healthy habitat	<b>6</b>	9.9	<b>12.0</b>	8.4	7.8
Balanced ecosystem/ Species structure*	<b>10</b>	7.1	9.0	5.9	5.1
Resilience to environmental change	<b>7</b>	7.6	7.3	3.8	<b>11.0</b>

The management objective given the least priority for management (i.e., the flyingfish fishery management objective given the lowest priority by all interviewed stakeholders combined) was the ecological well-being objective Sustained Ecosystem Health. The management criterion with the weakest average combined weight is *Balanced Ecosystem*. By country, the lowest priority management criterion in Barbados, Tobago, and Saint Lucia respectively is *Affordable Food Source*, *Resilience to Environmental Change*, and *Fair Access to Fishing*. In each country, and combined in both phases overall, these management criteria are consistently among the lowest three priorities. It must be emphasized that even management criteria with the weakest weightings have still been identified by stakeholders as important for flyingfish management.

When comparing the relative importance of weights between phases (i.e., between the flyingfish fishery in-season (phase 1) and when the season was closed (phase 2), the overall ranked importance of the management criteria remains essentially the same (Table 11). Four of the top 5 criteria are the same although the ordinal ranking differs throughout. The most evident change is with *Healthy Habitat*; this criterion was ranked second overall in the first phase during the fishery in-season and without sampling from Saint Lucia but dropped to sixth in the second phase and therefore in the combined rankings. Phase two has twice the number of respondents (N=77) than phase 1 (N=37) because it also includes respondents from Saint Lucia.

Table 11: Comparison of criteria weights (%) between phases one and two. Phase one weights have been modified to reflect changes made to the methodology in phase two.

<b>Operational management objective (criterion)</b>	<b>Phase 1 (In-season)</b> N=37	<b>Phase 2 (Off-season)</b> N=77	<b>Combined (Both phases)</b> N=114
Sustainable resource	<b>15.4</b>	<b>12.3</b>	<b>13.3</b>
Accurate information and monitoring	<b>10.8</b>	<b>11.9</b>	<b>11.5</b>
Effective management strategies	10.0	<b>14.4</b>	<b>13.0</b>
Optimized income from fishing	<b>10.2</b>	<b>10.5</b>	<b>10.4</b>
Fair access to fishing	6.8	7.7	7.4
Affordable and available flyingfish for food	7.3	7.6	7.5
Successful processing and export market	<b>10.3</b>	<b>13.0</b>	<b>12.1</b>
Healthy habitat	<b>14.4</b>	7.7	9.9
Balanced ecosystem	7.5	6.9	7.1
Resilience to environmental change	7.1	7.8	7.6

For all three countries combined, the cardinal importance (i.e., the spread in magnitude between weighted management criteria) between the management criterion identified as having the greatest priority (*Sustainable Resource*) and the criterion given the least priority (*Balanced Ecosystem*) by interviewed stakeholders is 6.2%. This difference is greatest in Tobago, where there is a 12% difference between the strongest-weighted criterion *Sustainable Resource* and the weakest-weighted criterion *Resilience to Environmental Change*. In Saint Lucia, this difference is 10% and in Barbados it is 7%.

In general, criteria assigned the lowest priority by stakeholders and therefore the weakest weighting had the smallest divergence or horizontal spread in priority ranking (Figure 10 (a-h)). Therefore, all respondents ranked these criteria with a similar (lower) importance, both within each country and for all three countries combined. Criteria identified as having the highest priority for management, and therefore the strongest weighting, tended to display a larger divergence or spread in weighting (and therefore ranking) by respondent. In Figure 10, frequency is the number of stakeholder responses represented in 5% criterion weight class intervals. For example, in the Panel g (Combined analysis - i.e., all sampled countries analyzed together), most respondents (N=34) weighted the criterion *Sustainable Resource* between 15.1% and 20%. The associated overall rank may vary depending on how many management criteria an individual has identified as being important. In the same Panel (g), for example, one respondent assigned *Sustainable Resource* a criterion weight of 53%, or the most important out of two selected criteria.

During the interview process a few respondents explicitly provided suggestions for additional management criteria that they felt were not adequately covered within the existing pack of cards. These criteria are: *Co-Management*, *Education*, and *Financial Investment*.



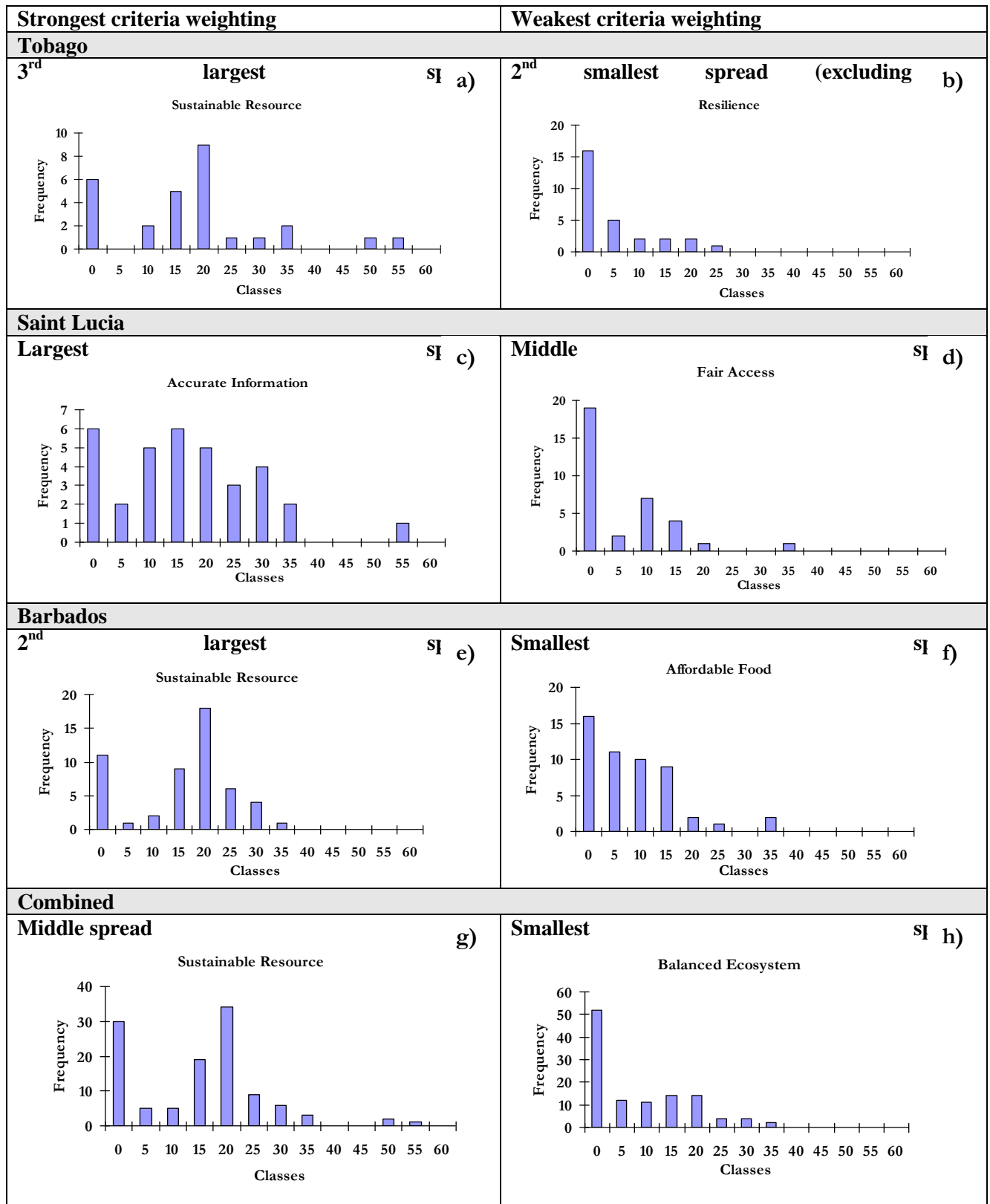


Figure 10: Panels a-h show histogram examples of the spread of stakeholder responses per criterion, where frequency is the number of individual stakeholder responses represented in 5% criterion weight class intervals. Top and lowest priority criteria are represented for each country and combined. Criterion concepts are abbreviated.

### 3.2.2 Management objective null responses

Interviewed stakeholders did not always rank all 10 management criteria in order of relative importance, choosing instead to identify only a few criteria as important to them. They would then arrange this smaller selection of criteria in a priority order for management. The lowest-ranked priority management criteria overall, *Balanced Ecosystem*, is also the most often discarded as a priority (Table 12); of the total 114 stakeholders interviewed, 52 individuals from all three countries combined, or 45.6% of sampled stakeholders, did not consider this criteria to be a priority for flyingfish fishery management at all. More than 50% of interviewees in Tobago and also in Saint Lucia did not identify *Balanced Ecosystem* as a priority.

Criteria comprising the ecological objective were often not identified as a priority for management by stakeholders. The criterion *Affordable and Available Food Source* was also consistently discarded by more than 30% of respondents. The management criteria most often identified by respondents as important in some capacity (both combined overall and individual countries) were *Effective Management* and *Successful Processing and Export Market*; around 80% of all sampled stakeholders placed some priority on these criteria, while 20% did not consider these criteria to be important to them at all.

*Table 12: Null responses per criterion, expressed as a percentage. 'Null' indicates that a criterion was not identified as important by an individual and therefore not ranked in the pairwise comparison. The largest percentage represents the most excluded criterion. The top 5 most excluded criteria within each country are in bold.*

<b>Operational management objective (criterion)</b>	<b>Barbados N=52</b>	<b>Tobago N=28</b>	<b>Saint Lucia N=34</b>	<b>Combined N=114</b>
Sustainable resource	21.2	21.4	<b>38.2</b>	26.3
Accurate information and monitoring	<b>26.9</b>	<b>32.1</b>	17.6	25.4
Effective management strategies	23.1	14.3	20.6	20.2
Optimized income from fishing	25.0	28.6	23.5	25.4
Fair access to fishing	<b>34.6</b>	28.6	<b>55.9</b>	<b>39.5</b>
Affordable and available Flyingfish for food	<b>30.8</b>	<b>32.1</b>	<b>32.4</b>	<b>31.6</b>
Successful processing and export market	19.2	14.3	29.4	21.1
Healthy habitat	<b>26.9</b>	<b>39.3</b>	<b>32.4</b>	<b>31.6</b>
Balanced ecosystem	<b>32.7</b>	<b>53.6</b>	<b>58.8</b>	<b>45.6</b>
Resilience to environmental change	<b>40.4</b>	<b>57.1</b>	20.6	<b>38.6</b>

### 3.2.3 Secondary data: Emergent Themes

In addition to eliciting a priority hierarchy of management criteria from stakeholders, the semi-structured 'Pack-of-cards' interview can also be used to record secondary data pertaining to each criterion during the conversation with the stakeholders. These data can provide the rationale for the weighting of criteria and their hierarchy prioritization by stakeholders. It can also be used to better understand flyingfish fishery stakeholder awareness, understanding, perception, and opinions about the flyingfish fishery, related ecosystems, and their role within the broader fisheries resource management system. They can also reveal additional and related major issues, cross-cutting themes, and even suggested management actions. These secondary data are organized and categorized here into broad emergent themes based on commonalities in stakeholder commentary (Table 13).

*Table 13: List of emergent themes compiled from secondary data in stakeholder interviews in both phases. These themes are based on common topics or language brought up by participants during the interviews and which may directly or indirectly point to potential areas of management priority focus. Here, comments are loosely classified by topics relevant to individual criteria and the number of comments relevant to each criterion is also tallied. \*Reef health was also often discussed but does not actually pertain directly to flyingfish.*

<b>Operational management objective (criterion)</b>	<b>Number of Comments</b>	<b>Emergent Themes</b>
Sustainable resource	53	<ul style="list-style-type: none"> <li>• Connection to sustainable livelihoods</li> <li>• Importance of spawning and abundance</li> <li>• <b>Management action suggested</b></li> </ul>
Accurate information and monitoring	42	<ul style="list-style-type: none"> <li>• Role of fishermen</li> <li>• Data quality and coverage</li> <li>• <b>Management action suggested</b></li> </ul> <ul style="list-style-type: none"> <li>• Importance of information for Mgt</li> <li>• Educating about information importance</li> <li>• <b>Information Sharing</b></li> </ul>
Effective management strategies	58	<ul style="list-style-type: none"> <li>• Training and education needs</li> <li>• Infrastructure needs</li> <li>• Industry health and safety</li> <li>• Cooperation</li> <li>• Communication and Consultation</li> </ul> <ul style="list-style-type: none"> <li>• Marketing and Investment</li> <li>• Regulation and enforcement</li> <li>• Nature as manager</li> <li>• Sustainable resource</li> </ul>
Optimized income from fishing	52	<ul style="list-style-type: none"> <li>• Market development needs</li> <li>• Processing profits, skilled labour</li> <li>• Supply and demand considerations</li> <li>• <b>Management action suggested</b></li> </ul> <ul style="list-style-type: none"> <li>• Vessel costs</li> <li>• Profit as social value</li> <li>• Stakeholder inequity</li> </ul>
Fair access to fishing	38	<ul style="list-style-type: none"> <li>• T&amp;T and Barbados conflict an inequities</li> <li>• Open access resource</li> <li>• <b>Management action suggested</b></li> </ul> <ul style="list-style-type: none"> <li>• Fish distribution affects abundance and access</li> <li>• Cooperation needed</li> </ul>
Affordable and available flyingfish for food	34	<ul style="list-style-type: none"> <li>• Cultural tradition of f.f. in diet</li> </ul> <ul style="list-style-type: none"> <li>• Supply and demand considerations in price</li> </ul>
Successful processing and export market	59	<ul style="list-style-type: none"> <li>• Infrastructure needs</li> <li>• Stakeholder inequity</li> <li>• General market development</li> <li>• Export market development</li> </ul> <ul style="list-style-type: none"> <li>• Domestic food security</li> <li>• Regulation and enforcement</li> <li>• Role of government</li> <li>• Skilled labour issues</li> </ul>
Healthy habitat	27	<ul style="list-style-type: none"> <li>• Marine and coastal development*</li> <li>• Pollutants</li> <li>• <b>Management action suggested</b></li> </ul> <ul style="list-style-type: none"> <li>• Water quality /Runoff</li> <li>• Reefs*</li> <li>• Illegal dumping</li> </ul>
Balanced ecosystem	37	<ul style="list-style-type: none"> <li>• Flyingfish and Dolphinfish links</li> <li>• <b>Management action suggested</b></li> </ul> <ul style="list-style-type: none"> <li>• Fishing practices</li> <li>• Connectivity to other fish</li> </ul>
Resilience to environmental change	43	<ul style="list-style-type: none"> <li>• Personal responsibility</li> <li>• <b>Management action suggested</b></li> </ul> <ul style="list-style-type: none"> <li>• Spawning and abundance fluctuations</li> <li>• Climate, water changes</li> </ul>

With regards to the secondary data, a further coding of qualitative data and subsequent cluster analysis could be conducted to reveal additional areas for consensus, collaboration, and conflict in flyingfish fishery management and other related fisheries.

### **3.3 Indicators of criterion performance**

#### **3.3.1 Status of data and information base**

A search for additional data and information to inform and support the operationalization of management criteria and the development of indicators and reference values identified very little additional information for public use beyond what is currently in hard copy or electronic publication. Both literature searches and site visits were conducted in both project phases. As a result, only a broad compilation of candidate indicators was compiled from the current literature in phase two. A preliminary list of “best available” criterion indicators, distilled from this compilation, is presented here, along with the organized and ranked objectives and criteria (Table 14), based on preliminary technical expert consultations. However, further discussions and conceptual development are necessary to develop a more robust and representative list of indicators from available data sources.

Table 14: Preliminary list of 'best available' criterion indicators. Objectives, criteria, and indicators are included here along with weights to illustrate how the MCA hierarchy fits together. See Leung et al. 1998 for an example of a completed hierarchy and scoring. Letters within parentheses indicate if the indicator is a pressure (P), state (S), or response variable (R). As indicators are refined and reference values developed, individual indicator scores can be elicited. Ultimately indicator scores and criterion weights are multiplied together to obtain a management outcome.

**Vision (WECAFC 2010):** Shared fishery resources in the eastern Caribbean will be collaboratively managed to give fair access to and distribution of benefits to all people in the eastern Caribbean region.

**Objective**

Ability to achieve: <i>Sustained fishery resource</i>	Human well-being: <i>Optimal use of fishery for social benefits</i>	Ecological: <i>Sustained ecosystem health</i>
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<b>0.380</b>	<b>0.375</b>	<b>0.245</b>
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**Criterion**

Sustain Resource	Accurate Info	Effective Mgt	Optimal Income	Fair Access	Affordable Food	Successful Process and Export	Healthy Habitat	Balanced ecosystem	Resilience to environment change
<b>0.133</b>	<b>0.115</b>	<b>0.130</b>	<b>0.104</b>	<b>0.074</b>	<b>0.075</b>	<b>0.121</b>	<b>0.099</b>	<b>0.071</b>	<b>0.076</b>

**Indicator**

Stock Status (S)	Type of data collected (S)	# of active fisher organizations (S)	Flyingfish fisherman gross profit (S)	Development of access agreements (R)	Average household income (S)	Development of facilities (R)	Development of Best Practices (R)	Ratio of relative biomass to predators (S)	Development of mitigation infrastructure (R)
Total Catch (S)	# of days of data collected per season (S)	Formality of management plan (R)	Price of flyingfish per kg (S)	Number of intra-resource disputes (S)	% landings available for domestic consumption (S)	Value of post-harvest production (S)			Development of disaster plan (R)
CPUE (P)	% collector coverage (S)	FMP clearly states goals and objectives (S)			Price of flyingfish (S)	Average export price per kg (S)			

## 4. DISCUSSION

The present evaluation of Multi-Criteria Analysis and complementary assessment tools explores only one possible methodology that can be applied to enhance the decision-making capacity of fisheries management while supporting more holistic and ecosystem-based approaches compared to conventional fisheries management. This discussion therefore assesses whether the MCA, based on the results of and the lessons learned from this evaluation as well as in relation to phase 2 goals, is an appropriate tool for facilitating complex decision-making, for improving the data and information base available for management and policy, and for supporting an Ecosystem Approach to flyingfish fisheries in the eastern Caribbean.

### 4.1 The MCA as a decision support tool

Multi-criteria decision-making and analysis is gaining popularity in sustainable resource management as a framework capable of addressing a range of decision-based issues involving conflicting and multiple objectives in situations of risk and uncertainty (Mendoza *et al.* 1999). When combined with complementary tools such as the Analytic Hierarchy Process, this tool can provide a systematic, traceable, and logical means by which to arrange, prioritize, and analyse multiple dependent management objectives, and from this consider multiple decision options to inform management practices (see Leung *et al.* 1998; Fernandes *et al.* 1999). This clear process can facilitate the communication of the rationale and logic behind complex decisions which, because it incorporates many individual judgments into its framework, may support a jointly-reached conclusion without having to reach a general consensus. In theory, these qualities make such a tool particularly appropriate for identifying and prioritizing multiple flyingfish fisheries management objectives in the eastern Caribbean. Having tested this methodology in practice, the strengths of the MCA and AHP largely hold true, with a few considerations.

Following the MCA framework did allow for a clearer representation of the regional flyingfish management plan framework as well as the linkages between management plan elements through the use of hierarchy tools. The inclusion of stakeholder input for the prioritization of management objectives using the Pack of Cards and pairwise comparison tools was found to be relatively cost-effective and easy in terms of collecting and using the information to systematically interpret it and generate management objective priorities as intended. That the prioritization of multiple and diverse objectives was accomplished while incorporating diverse stakeholder opinions across multiple countries speaks to the strength of this tool in generating clear and stakeholder-influenced priorities for management decision-makers. This incorporation of multiple views into decision-making indicated by the multi-modal distribution of criterion weights in the analysis, has the potential to strengthen stakeholder buy-in into management decisions and in turn the effectiveness of management actions. However, the semi-structured interview process itself requires sufficient time and applying the pairwise analysis in the field was challenging at times. While it was found that the semi-structured interviews allowed for a more inviting and individual opportunity to collect data-rich information, if time constraints are a major barrier to incorporating stakeholder input into multi-objective decision-making, a more structured and time-conscious interview format may be more appropriate. However it is also important to consider that the access to and availability of fishermen given their work schedules and location will unavoidably add time to the interview process and this could complicate sample size considerations. For more widespread routine application in practice, this issue could be addressed to some extent by adding one or more interviewers, and increasing the number of sampling days.

For the purpose of this exploratory study, the selection of management elements was completed using a more top-down approach – from the literature and with some consultation with stakeholders. However, for actual application, an effective management framework could easily employ a more bottom-up approach to selecting management elements by consulting with fishery stakeholders and deriving a goal and set of objectives that more strongly reflects the priority needs and desires of fishermen, processors,

vendors, management, and other stakeholders. This additional involvement of stakeholders could further strengthen management decision-making capacity.

With regard to the use of the ‘pack-of-cards’ approach as a tool to solicit priority rankings for and stakeholder opinions on management criteria, this uncomplicated approach appeared to elicit the desired information well and was generally easily explained and understood by both interviewer and interviewee. The tactile element of the method appeared to facilitate the organization of some stakeholders’ thoughts during the ranking process. In Barbados, for example, some respondents arranged cards in an ordinal “storyboard” format to clarify to themselves and to the interviewer their rationale for their individual prioritization of criteria. This also illustrates many stakeholders’ awareness of the connectivity and sequential processes that must occur between multiple management actions; this impression was further reinforced by stakeholder comments such as “How am I supposed to pick which [criteria] is first? These are all connected.” or “This [criteria] has to happen before this one can”. However, arranging criteria in order of relative importance was not easily grasped or executed by all stakeholders; getting a participant to commit to an order of importance was often difficult and a ranking of all ten criteria happened infrequently. Some stakeholders found it easier to work with priority groupings of criteria they perceived as closely linked. This said, the process was new to stakeholders, and the difficulties experienced by stakeholders for this study would be expected to diminish with time if the process were to become an integral part of management procedures.

The structure and content of the interview also meant that a lot of information was presented to stakeholders to process very quickly. This more than likely influenced the prioritizations made by interview respondents, who by necessity had to go with a “gut response” in the Pack of Cards exercise. Some stakeholders expressed that what they were being asked to do would require some time for reflection if they were to complete the exercise properly considering the concepts involved and the idea behind it. Some felt that they did not have enough knowledge on a particular topic to comment effectively. It is possible that given time to reflect on the concepts and their linkages that stakeholder responses could have differed because they had a longer time to consider how things might fit together.

In analyzing the survey responses from the AHP and the pack of card survey tool, it is evident that while the regional integration of policies between flyingfish resource-linked countries may be uneven or lacking, and between-country priorities may differ, common traits exist between regional stakeholders with respect to their views and values of the fishery and in their exposure to and comprehension of management objective topics. For example: the most highly ranked and heavily weighted criterion *Sustained resource* required little clarification among stakeholders in all three countries. Given the prominence of the concept in the language of management and policy, stakeholders may have the most familiarity with this concept and its importance in comparison to the other objectives. However, in reviewing the secondary comments, this strong weighting is likely also of a reflection of many stakeholders’ acute awareness of the close linkage between the well-being of flyingfish and the well-being of their livelihood. On the other hand, not all fishermen prioritized this criterion highly - the concept of catching too many flyingfish to the point that future catches could be negatively affected was dismissed by a number of fishermen who cited the favourable annual life-history and comparative stability and abundance of the regional population. Those common views, values, and knowledge among stakeholders in the different countries could be further explored, enhanced, and used as a starting point for more collaborative regional decision-making initiatives.

This exercise highlights the willingness of many stakeholders to engage in the fishery policy cycle given the opportunity, how information is differently understood and processed by stakeholders, and how they see themselves fitting into the management cycle. In this regard, in analyzing the weighted pairwise comparison outcomes it is apparent that while stakeholders identify ‘effective management’ as a key element to sustaining a fishery resource, they generally consider themselves external to the management

decision-making process rather than an integral part of it. There was a strong trend among interviewed fishermen to identify the importance of personal responsibility in a responsibly managed fishery, as well as a recognition that this aspect needs to improve. Paradoxically, however, this assessment seldom extended to self-reflection among surveyed respondents.

What was made most clear from this exercise in terms of decision-making support was that while management plans relevant to flyingfish may contain well-rounded objectives which include a range of social, economic, and environmental considerations, there is still a considerable divide between objectives and their operationalization in the case of the flyingfish fishery. There is also very little information available to infer whether objective criteria have been implemented in any of the analysed countries and virtually no information as to whether their functionality in achieving overarching management goals has been assessed through the use of indicators, reference values, or other means. This means that, at this time, the application of a full MCA for flyingfish fisheries management policy is hampered by conventional data limitations for evaluating the success of management decisions, namely the existence of indicators and reference values of success. This exercise did, however, both confirm and highlight potential priority areas of focus for data and information improvement.

#### **4.2 The MCA as a tool for improving the data and information base**

The MCA and related components proved effective at providing stakeholder prioritization information for management, at identifying the need to strengthen the clarity and operability of existing management objectives, and at highlighting that further work could be done to bring stakeholders into the management cycle and recognize their valuable role within it. However, with respect to measuring the performance of existing management elements, the MCA was more effective at revealing data deficiencies.

Because an MCA seeks to encapsulate the complexity of a natural system into decision-making it has the potential to be data-intensive. This poses a particular challenge in a region with limiting institutional and financial resources such as the eastern Caribbean. When considering an MCA to assess a particular policy issue, the setup must carefully consider the availability and accessibility of data necessary to support such an analysis. This is particularly true when attempting to incorporate indicators to measure performance in relation to goals and objectives. With flyingfish in the region, the data used to support policy feedback relating actions to goals, in particular reference points, trajectories, and directions, are lacking in the information base for informing such an assessment. Having only draft management objectives and criteria, minimal direct input from stakeholders, and based primarily on biological and economic indicators of success which may be years out of date, the status of flyingfish fisheries is nonetheless accepted as stable by conventional standards.

Based on primary industry stakeholder comments in all three study countries with respect to the accuracy and coverage of catch data for flyingfish and with the confirmation that bait fisheries aren't currently being monitored, the current biomass removals of flyingfish from the ocean in the eastern Caribbean are almost certainly underestimated, and possibly by considerable quantities. Data that could assist in better defining the scale of this issue are updated information on the number of fishermen, what is being caught and used for bait and where, estimates of quantity, the number and capacity of boats fishing, and number of days and percent reporting coverage for catch monitoring and data collection across national landing sites.

WECAFC (2010) compiled some biological and socioeconomic flyingfish fishery indicators for different countries in the region; however data were incomplete and outdated even at the time. An update of this data closer to the present date would greatly improve the baseline information available for fishery analysis. Social and economic data which relate fishermen's reliance on the fishery, and ecological data, relating the state of ecosystems are also in need of improvement. An update of more recent numbers of primary and secondary industry participants, with a breakdown of which fisheries they are involved in



and their full or part-time status could go a long way in indicating the changes in the fishery in the past decade and give a better indication of the social well-being status of the fishery. For example, in Tobago it was found that the number of major flyingfish processors on the island had dwindled effectively to 3, a much lower number than given in the national reports. In speaking with some of these processors during the interview process it was made clear that even they were struggling to remain cost-effective. In seeking out interview participants, the number of fishermen identifying as flyingfish fishermen also appears to have declined significantly from national reports, with many stating that the price of flyingfish was too low for them to put in the effort to catch them for anything other than bait. Updating the amount of financial investment and subsidies applied to the industry would also provide valuable information on the overall well-being of not only the flyingfish fishery, but the fisheries in a given country more broadly.

In this regard, a small socio-economically-focused census conducted during one of the routine catch and effort data collections in each country could greatly improve the information available for fishery analysis. Data such as average income, income as a proportion of household income, and the average price per unit of flyingfish or estimated net fishing trip revenue would provide good socio-economic well-being indicators, particularly for primary industry participants. Such a census was recently conducted in some countries in the region (CRFM 2012), and these data could be incorporated in further practical applications of MCA. In Barbados, UWI and collaborators have made great advances in improving the broader social-economic information database available for coastal resource managers both in the Caribbean and more broadly through the SocMon project and affiliated publications ([http://cermes.cavehill.uwi.edu/socmon\\_project.html](http://cermes.cavehill.uwi.edu/socmon_project.html)). Determining ecological indicators for the well-being of not only flyingfish but pelagic fish more generally could also benefit from further dialogue as to how to measure and determine ecosystem well-being.

#### **4.3 The MCA as a tool for supporting an Ecosystem Approach to Fisheries**

In supporting increased stakeholder participation in this policy cycle development exercise, the MCA supports this aspect of a more holistic Ecosystem Approach. The pack of cards and pairwise exercise also showed that it is capable of incorporating a range of social, economic, and environmental information into management priority decision-making. It also became clear that the linkages between flyingfish and other fisheries were strong and that it was often difficult to disentangle the desired priorities of this fishery from others. Because of its strong connection to other fisheries and because it is often not an exclusively targeted fish for capture (except in Barbados), flyingfish fishery stakeholders are by their nature multi-species fishers. Perhaps because of this there was some difficulty in getting interview respondents to comment on only flyingfish interests during both the phase 1 and phase 2 prioritization exercises. It is therefore likely that management objective priority weightings for flyingfish were influenced by a broader conceptualization of fisheries management. For example, in analyzing the secondary data commentary for context, the high priority weighting of *Healthy habitat* in Barbados is almost certainly a reflection of expressed conflicts between near-shore tourism development and reef fisheries rather than for flyingfish. Also, in Saint Lucia, the *Successful processing and exports market* criterion ranks as a high priority, despite the assertion by fishermen that one does not currently exist for flyingfish, and that they are generally satisfied with domestic flyingfish markets. In looking at the secondary comments for clarification, while there was a desire expressed among some stakeholders to establish value-added markets for a better spread of financial and employment benefits, many comments could actually be attributed to large pelagic fish, in particular tuna. This highlights the importance of considering a broader context and connectivities to other fisheries when analyzing stakeholder prioritizations for a particular fishery. This broader conceptualization could be interpreted as indicative of the fact that fishermen are already applying their own 'ecosystem approach' to how they view and value the flyingfish fishery in the context of other fisheries and their own social well-being.

This broader view did have its limitations, however. Explaining that the management objectives and criteria in the exercise were conceived to be regional in scale was largely not well-grasped by

stakeholders other than by some in administration. Including this aspect in the explanation of concepts preceding the organization process was abandoned in favour of letting participants consider criteria at more local scale – where they would feel the direct effects of management action. Among fishermen, the criteria concepts within the ecological objective were also not well-grasped on the whole; this may partially explain the weaker overall priority weighting of these criteria in the pairwise comparison exercise. This is likely due to a combination of factors. All three ecological criteria were large, abstract and relatively academic concepts. These could have been better contextually framed within the methodology to reflect the stakeholder audience. For example, in looking at secondary comments for clarification and context, most fishermen know that there should be more prey species than predators in a healthy ocean and that too much of one species can negatively affect the abundance of another, but not that this is academically referred to as a “balanced ecosystem”.

The overall lower weighting of the ecological objective may also indicate recognition that, for flyingfish, these particular ecological issues may be a low priority in relation to other more pressing priorities in other fisheries. Given the number of negative comments about other fish and fishing practices in the secondary data (e.g. reefs, snapper, tuna) this is a distinct possibility. It may also, however, speak to the difficulty in addressing pelagic habitat issues. For example, fishermen didn’t appear to identify FADs with a healthy habitat, but nearly all saw them as important for creating areas for pelagic fish to aggregate. The resolution of environmental issues was also often identified as being something largely out of management’s control and that personal actions were the solution to mitigating and adapting to ecological issues. That fishermen in all three countries generally perceive themselves as external to management highlights an area in which further education and collaboration could take place.

Overall, however, the Pack of Cards method was effective at identifying that flyingfish fishery stakeholders, in particular fishermen, are naturally holistic thinkers who are aware of linkages and sensitive to changes in the whole system. While they may not always excel at identifying their own role in the broader management and ecological system, they have a wide-ranging knowledge about human and ecological interactions that could be better utilized and appreciated with increased consultation. Furthermore, the prioritization exercise indicates that fishermen, vendors, and processors are willing to engage and participate in policy cycle development given the right environment to do so. These points all suggest that the groundwork for participation in an EAF may already be in place.

#### **4.4 The MCA and performance indicators**

In an Ecosystem Approach to Fisheries, indicators can provide valuable information on the state of an ecosystem, the human pressures exerted upon it, and the response of management with regard to translating objectives into action (Jennings 2005). The application of indicators to assess management objective performance is therefore reasonably data-intensive because it requires both quantification and an understanding of the system being measured in order to develop reference points, directions, or trajectories. These reference values provide the benchmark by which an indicator is measured, which in turn provides guidance for management action. The selection of readily measurable indicators is therefore particularly challenging in data-poor situations. As a result, the indicator selection process for this evaluation was most strongly dictated by the limited availability of up-to-date data for informing reference points. Further development of the information base, discussed previously, and the manipulation of existing data into scaled measurement indices are necessary before the quality of indicators selected for this evaluation can improve.

Before these measures of management objective performance can be further developed and reference values determined, however, more formalized discussions need to take place between stakeholders as to what their vision of success for the regional flyingfish fishery might look like (i.e. beyond the draft stage). Making this overarching management element clearer would necessarily clarify the desired fishery outcome and in turn the steps towards achieving and measuring its success. Given additional time and

expert consultation to select representative indicators of management element performance, it is likely that some biological and socio-economic indices for flyingfish could be developed with some of the current data available in Barbados (Staskiewicz *et al.* 2008), and possibly in Saint Lucia as well. However, much of these data are in need of an update before they can be used as relevant measures for current management purposes. As well, flyingfish fishery-specific data and the availability of ecological data even for Barbadian fisheries remain underrepresented. Flyingfish fishery data quality and availability need to improve significantly in Tobago before management objectives can be evaluated. The data and information-intensive nature of indicators raise the issue of whether they are the best tools for the assessment job in developing countries with limited financial and institutional resources for adding to databanks. However, as all three countries have existing data collection protocols in place, the occasional addition of census surveys while collecting routine information on catch and effort could make use of abundant stakeholder knowledge and contribute to more robust management strategies and evaluations.

#### **4.5 Additional considerations**

This assessment could be enhanced and additional data and information generated by including coding and statistical analyses of stakeholder data. Further statistical analyses of results may include an investigation of response error and consistency, principal component analysis, and clusters of non-parametric stakeholder responses. Lessons learned and knowledge gained in the field could be applied to further refine the MCA process and compared to similar experiences in the literature. Consulted stakeholder groups could be expanded both in terms of sample size and in the diversity of groups consulted. Additional consultations to further develop indicators, reference values, and scoring metrics of criterion performance would both increase the information available for decision-making and clarify desired fishery management goals in relation to present conditions. A further development of indicators could include a more in-depth exploration of how best to use existing data to develop performance indicator indices, e.g. indicators of social dependence on the flyingfish fishery, of opportunity cost, of productivity, or of spatial coverage of data collection or fishery activity. In further developing these indicators and scoring metrics while considering the wide range of contributing data types, further direct dialogue will need to occur between administrators, fishermen, and other fishery stakeholders in order to define what is meant by a “successful” flyingfish fishery in the eastern Caribbean, not only for the biological qualities of the resource, or the money and jobs it generates, but also for the well-being of people, of management systems and of the supporting ecology. The development of a range of decision-scenarios for flyingfish fishery management action could also be explored to assist in this regard.

#### **4.6 Conclusion**

Many people in the eastern Caribbean rely on flyingfish fisheries either directly or indirectly for their jobs, livelihoods, and well-being. The interconnectivity of this fishery to other fisheries in the region, the regional nature and cultural importance of the resource, and existing resource user conflicts invite a more holistic management approach that both embraces the complexity of multiple objective decision-making in fisheries management and incorporates greater stakeholder input. As an exploratory exercise, the application of a MCA assessment tool and its complementary components have shown that even in situations of conflicting and multiple objectives among transboundary resource users, relatively simple methods can be developed, modified, and applied that incorporate a diversity of stakeholder values, opinions, and priorities into fisheries management frameworks with relative equality. Over one-hundred individual opinions from different flyingfish fishery stakeholder groups in three different eastern Caribbean countries contributed to a collective prioritization of management objectives for one regional transboundary fishery. Individuals in this fishery, despite localized differences, collectively value, above all else, a sustained flyingfish fishery resource complemented by effective management strategies which promote successful post-harvest markets and are supported by accurate and accessible information. These same stakeholders are also willing, given a positive approach, to collaborate, share, and provide input into management action.

The draft status of management plans for flyingfish and the gaps in the available data and information base are not currently such that indicators and reference values of performance can be readily derived for a complete MCA assessment of the eastern Caribbean flyingfish fishery. Nevertheless, this exploratory exercise also shows that fishermen, small-scale processors, and vendors of flyingfish in the eastern Caribbean are already holistic thinkers who consider multiple species, fishing activities, and ocean ecosystems in their decision-making, often in the absence of tangible data. However, these same broadly-thinking individuals may struggle to see and to understand their own role within the broader fisheries management system, and in the state of the fishery and marine species ecosystems on which they rely for their livelihoods and well-being. Based on this observation, more work could be done to legitimize the role of management in the daily lives of stakeholders, in particular fishermen, and to help them to realize that they are a part of, and not external to, an effective management system and a healthy, ecosystem-based fishery. The reward in doing so may be a fisheries policy cycle with reduced conflict, improved transparency, communication and participation, increased social and institutional capacity, and a fisheries resource that benefits from more responsible use.

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# EXPLORING THE USE OF AN ECOLOGICAL RISK ASSESSMENT TOOL FOR MANAGEMENT OF THE LARGE PELAGIC FISHERY IN THE EASTERN CARIBBEAN

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## Abstract

In the present study, we explored aspects of the Ecological Risk Assessment for the Effects of Fishing (ERAEF) method to assess the relative risks to target, bycatch and threatened, endangered or protected species (TEP) that could be negatively impacted by the large pelagic fishery of the Eastern Caribbean island states. A list of all species caught by the hook and line fishery of the selected states was compiled and analyzed to determine the relative importance of individual species to the region. Using ERAEF method application guidelines, a general descriptive survey and hazard identification of the Eastern Caribbean large pelagic fishery was completed. This stage of the analysis was informed by both a literature review, as well as consultation with a range of stakeholders. The second stage of analysis, a Scale-Intensity-Consequence Analysis (SICA) that included development of agreed operational objectives and further analysis of identified hazards related to these objectives, was subsequently completed for key components. The SICA was informed through consultations with scientific experts with intimate knowledge of the existing fisheries. Lastly, a semi-quantitative Productivity-Susceptibility Analysis (PSA) was conducted using available scientific data for the most important commercial species. In terms of our findings, we identified a number of hazardous activities associated with fishing, as well as hazards caused by non-fishing activities such as seismic surveys conducted by the petroleum industry and general large-scale shipping activities. Additionally, of a total of 39 target species (classified into high-priority and low-priority target species) considered in the analysis, 18 target species were found to have low vulnerability to the hazards identified and 21 had medium vulnerability. Interestingly, most of the medium-vulnerability species were actually low priority target species. It is clear that capacity to make full use of ERAEF and its application potential would require that countries invest resources in a broader level of monitoring than is currently the case for many CRFM fisheries. Partnerships with research institutes and other economic sectors of government could assist in broadening the nature and quality of fishery and fishery-related data captured, and by this means, create the capacity required for informing more holistic fisheries management.

## **1. INTRODUCTION**

### **1.1 Ecological Risk Assessment**

Risk is defined as a hazard, measured by the chance that a chosen activity will lead to an undesirable outcome. Ecological Risk Assessment (ERA) is a process that attempts to assign a degree or magnitude of risk of adverse effects on ecological components, arising from human interference, environmental changes and/or disasters (Suter 1993, Burgman 2005). The basis of ERA is a preventative, qualitative approach that measures potential risk to the ecological components of the environment, and by this means, can generate useful information for informing conservation and management responses.

ERA for the effects of fishing (ERAEF) is a hierarchical, precautionary tool to assess vulnerability of aquatic species to fishing pressure. Such an assessment examines biological, ecological and environmental data and information, and in so doing, can generate information to facilitate an ecosystem approach for sustainable management of important fishery resources. The information generated can also help to focus scientific resources on the most important ecological problems associated with fishing, and thereby, offers an efficient method towards Ecosystem Based Management (EBM). The ERAEF was developed through a joint initiative carried out by the Australian Commonwealth Scientific Industrial Research Organization (CSIRO) and the Australian Fisheries Management Authority (AFMA) (Hobday *et al.* 2007). As already indicated, this approach is hierarchical in nature. Based on available data, the analysis moves from a broad, qualitative Level 1 Scale-Intensity-Consequence Analysis (SICA) to a more focused semi-quantitative Level 2 Productivity-Susceptibility Analysis (PSA) and finally to a fully quantitative stock assessment Level 3 analysis (see Figure 1 in Hobday *et al.* 2007). The qualitative analyses of ERAEF are not only useful for data-poor situations, but provide an initial measure of the relative risks to the species of interest and this is used to focus research and management resources and effort where these are most needed (Stobutzki *et al.* 2001). Low-risk activities and species are thus screened out at each successive stage to focus attention on those areas that are at the highest risk. Also, ERAEF facilitates a precautionary approach because in the absence of sufficient data, a high risk is assigned. The tool makes use of existing forms of knowledge, data and information, facilitating management actions even in situations of limited time and finances.

### **1.2 Development of ERAEF and some management applications**

Prior to the development of ERAEF, original Ecological Risk Assessment models for fisheries were general and qualitative in nature, similar to the Level 1 approach (Fletcher *et al.* 2002). A semi-quantitative method also existed for specific components (in particular, by-catch) from which the Level 2 PSA approach was derived (Stobutzki *et al.* 2001). Additionally, until recently, there have been few ERA applications to large pelagic fisheries. The ERAEF methodology has been developed, modified and recommended for fisheries management purposes by several international entities including the Australian Fisheries Management Authority (AFMA) (Hobday *et al.* 2007, Smith *et al.* 2007), the Lenfest Ocean Program (Rosenburg *et al.* 2007), the International Commission for the Conservation of Atlantic Tunas (ICCAT 2008), the Marine Stewardship Council (MSC 2010) and the United States National Oceanographic and Atmospheric Administration (NOAA) (Patrick *et al.* 2009). Aspects of ERAEF, namely, PSA, have also been applied to groups of bycatch species not normally focused on by research or management bodies, and so as an approach to better achieve ecosystem based management solutions. Examples of such assessments have included species groups such as: pelagic sharks by Cortes *et al.* (2010); marine mammals, turtles, sharks, teleosts and marine birds by Kirby (2006); and a seabird assessment conducted by ICCAT (2008) to identify those species most at risk from pelagic longlining fisheries the target species for which the status is usually evaluated via full quantitative assessments.

### **1.3 Exploring ERAEF application in CRFM fishery situations**

The Caribbean Large Marine Ecosystem (CLME) project was established in 2009 with the vision to move toward the common goal of sustainable management of shared living marine resources (LMR) within Caribbean waters using ecosystem level approaches. Towards this end, the project is also examining



options to improve the required governance systems (Fanning *et al.* 2007). Given the transboundary nature of large pelagic fish resources, efforts are needed at the national, regional and international levels to improve sharing of data and information for sustainable use and management. In this regard, application of the ERAEF method serves to inform data and information needs, especially for those biological and ecological components of major and common interest. Additionally, the ERAEF model is beneficial in data-poor fisheries such as the Eastern Caribbean, because of its hierarchical organization and incorporation of precautionary interpretations.

#### 1.4 Study Area and a Fishery Profile

The Lesser Antilles comprise part of a long volcanic island arc, located in the Eastern end of the Caribbean Sea, in the Western Central portion of the Atlantic Ocean. For the purposes of the present study, we considered the fishing areas of the following Eastern Caribbean countries that have active large pelagic fisheries: Dominica, St. Lucia, Barbados, St. Vincent and the Grenadines, Grenada and Trinidad and Tobago (Table 1). The Pelagic zone, meaning areas of the ocean not associated with bottom or coastal features consists of three sub zones: 1. Epipelagic (from the surface to 200m depth); 2. Mesopelagic (between 200-500m depth); 3. Bathypelagic (>500m depth).

Table 1.: Countries considered in analysis and their respective EEZ area. (Source: seaaroundus.com)

CARICOM Member State	EEZ (km <sup>2</sup> )	Landing Data Used in Analysis
Antigua & Barbuda	107, 914	
St. Kitts & Nevis	10, 201	
Montserrat	7, 582	
Guadeloupe	95, 978	
Dominica	28, 626	X
Martinique	47, 640	
St. Lucia	15, 484	X
St. Vincent and the Grenadines	36, 314	X
Grenada	26, 158	X
Trinidad & Tobago	77, 502	X
Barbados	186, 107	X

Pelagic fisheries in the study area are diverse and complex, involving artisanal, commercial, industrial and recreational fisheries using a variety of gears on different types and sizes of vessels, targeting a variety of species. The hook and line fishery, both trolled and stationary, includes gear such as longlining (LL), handlines (HL) and rod and reel (RR). Research and data collection for many coastal and industrial fishing countries, such as those included in our study, are incomplete (ICCAT 2007).

Historical (Pre-1950) fishing methods were reported to use sail or oar-propelled boats that would use single pieces of strong line (breaking strain of about 70lb) a lead of a bit of wire and pieces of flyingfish on single, poorly made hooks. The fishery developed to incorporate small wooden boats (double-enders) with 10-30HP outboard engines carrying a crew of three men. Each crewmember would use two handlines between 150-180m in length with one hook/line. The boats would launch at dawn, and search for flocks of working birds as an indicator of good fishing grounds. Fishers would return at dusk with their catch. In the 1980's and 1990's surface longlining was introduced into Grenada with help from the Cuban government and became increasingly more popular. Larger fiberglass re-enforced vessels (pirogues) with larger engines were introduced. Old twisted strain lines deployed from an onboard box developed into a nylon monofilament mainline that was deployed by reels, and stainless steel J and circle hooks began to be baited with both artificial lures and fresh bait. Iceboxes were installed on many vessels

(termed an iceboat). Catch effort grew to over 300hooks/set in some cases. The present fishing fleet in the Lesser Antilles now consists of a variety of vessels, gears and technologies from the small open boats to large longliners (CFRAMP 2001; Grant and Baldeo 2006).

## **1.5 Current Management & Justification of study**

Large pelagic species are important worldwide, both socially and economically, for industrial, small-scale, artisanal and recreational fishing operations in offshore waters. In the Lesser Antilles, large pelagic fishes are considered to have the greatest potential for fishery development and most island states have already begun to increase their efforts in this fishery (Chakalall and Cochrane 2004). The fishery sector is vital in the region as it provides a primary food source for local populations, contributes to the region's tourism sector, and generates employment and income opportunities to over one million Caribbean people (Mohammed *et al.* 2008). Important socio-economic pelagic species within the CLME in the Western Central Atlantic can be described in two categories: 1) Highly migratory oceanic species whose stocks extend outside the CLME bounds (e.g. Large migratory tunas, Billfishes and others); and 2) Coastal species whose stocks are considered to be more or less contained within the CLME area (e.g. Wahoo, Dolphinfinh, smaller tunas and Mackerel species) (Singh-Renton *et al.* 2010). The management body responsible for the management of tuna and tuna-like species is the International Commission for the conservation of Tunas (ICCAT). The majority of assessment efforts by ICCAT have focused on those species that support the highly profitable commercial and recreational fisheries, namely, species from category 1. Category 2 species have received less attention by ICCAT, which has argued that in view of their expected coastal distributions, these species should be managed at the sub-regional levels (ICCAT 2007, Singh-Renton *et al.* 2010). ICCAT (2012) further noted the importance of the coastal small tunas as prey for the larger tunas and billfishes, and noted that stocks assessment could also be addressed from the ecosystem perspective.

As a result of basic and imperfect data collection systems in many of the island states of the Caribbean, the statuses of several large pelagic fish stocks in the region, especially those of the small tunas and tuna-like species, are poorly known. In addition to the management advice provided to Eastern Caribbean states by the ICCAT process (Singh-Renton 2010), the present study explores application of the ERAEF method to identify some of the data deficiencies and hence data improvement needs within an ecological context, and to provide preliminary results of the ecological impacts of fishing on several large pelagic species.

In particular, the present study uses ERAEF to provide a range of vulnerabilities for the most important large pelagics landed by the Eastern Caribbean island states by hook and line fisheries. Following the modern, international EBM framework approach to fisheries management we consider a variety of species, instead of the traditional approach of considering a single isolated stock. The main focus of the current ERAEF is the PSA analysis, although it is narrower in scope than the SICA analysis, as it focuses primarily on the actual, tangible effects of fishing (Cotter & Lart 2011).

## **2. METHODS**

### **2.1 Scoping: A fishery Profile**

#### Generating Units of Analysis Lists: Species

As a first step, a comprehensive species list of all large pelagic species landed or interacting with the hook and line fishery of the study area was generated using various information sources including web libraries, fisheries division data, ICCAT and FAO databases. Landings data were provided from Fisheries Division/Department personnel for the eleven-year period (2000-2011) for only two of the six CRFM member states included in the present study (St. Vincent and the Grenadines and Grenada). As a result, the ICCAT Task 1 database of nominal species caught within the region was used to obtain large pelagic fish landings data for the remaining four states studied. Where applicable, missing data were then supplemented by the FAO statistical databases using Fishstat software for the same period.

The relative importance of a species to the study area was determined based on species catch levels reported by countries, and also the number of countries reporting a species. Being a multi-target species fishery, the terms “by-catch” and “by-product” were determined to be inappropriate for the purpose of our study. This is because all other large pelagic fish species caught (not previously listed in our “high volume target” list) would normally be retained and sold: in contrast, “by-catch” infers that those species would be caught only incidentally and would be returned to the sea and “by-product” infers a secondary product derived from processing the primary product.

Based on examination of the weight landed criterion, we produced a prioritized list of species caught for each individual state and also collectively over all six selected member states. A species became a “high volume target” species for the purpose of our analysis if its cumulative landings  $\geq 100$  tonnes for the 11-year period studied. The twenty-three species that fit this category were termed our “high volume target” species for the purpose of this analysis. A species became a “low volume target” for the purpose of our analysis if its landings equalled or fell between 0.1 and 99 tonnes in the 11-year period studied. The seventeen species that fit this category were termed our “low volume target” species.

A third list of species was created using the incidence of a species ever interacting with the hook and line tuna fishery in the Atlantic Ocean, which was obtained from the ICCAT database (available at: <http://www.iccat.int/en/bycatchspp.htm>) including information from three basic sources: (1) catch reports by the different participating countries, (2) scientific documents presented to the ICCAT Standing Committee for Research and Statistics, and, mainly, (3) a survey in which each country’s experts identified the species that have ever interacted with their fisheries. This list contains all species (teleosts, chondrichthyans, marine mammals, marine reptiles and marine birds) and is broken down by gears operating in the Atlantic (i.e. baitboat, gillnets, harpoon, longline, purse seine, traps and others). This list does not provide quantitative information of the species caught, the rate of occurrence within the fishery, or the survival/death rate of the species interaction with the fishery, but merely lists those species that have ever interacted with a particular gear in the ICCAT Convention area. As some species caught were only identified to the genus and not species level (i.e. “Ground sharks”), those groupings of species were eliminated as to avoid duplication of analysis. We also eliminated those species that were identified as ‘not occurring’ within the study area. From this list, we established a new list of the threatened, endangered or protected (TEP) species using the IUCN red list status for each species, which takes population trends into consideration (IUCN 2011), and the intrinsic vulnerability for species (where available) (Cheung 2005, 2007), which takes into account vulnerability based on life history traits. We then supplemented this list through verified scientific literature, stakeholder interviews and profiles of oceanic and coastal marine birds (Lee 2009). The final “TEP” species list contains 65 species.

## **2.2 Stakeholder Consultations**

Field visits to islands represented in the present study yielded a total of 49 fisherfolk interviews (20 and 29 for Barbados and St. Lucia, respectively). These interviews were carried out at various landing sites within the 2 islands. A standardized questionnaire was developed to refine our understanding of the fishing situations at present, and so we gathered information on: fishing grounds/season/value, characteristics of vessel operations, gear characteristics and bait. The results from these interviews were summarized and incorporated to provide a current description of the fishery that contributed to the scoping stage of analysis.

During the 2011 and the 2012 CRFM Scientific Meetings, the Large Pelagic Working Group with a broad range of scientists, fishery experts and consultants, reviewed, validated, and provided additional inputs into the analyses conducted and conclusions for the first two stages of the present study. In particular, during the 2011 scientific meeting, the Scoping and Level I SICA analysis were further developed

(CRFM 2011). The PSA results were presented and validated during the 2012 Scientific Meeting (CRFM 2012).

### **2.3 Information Collection and Data Quality**

Uncertainty of data was scored and indicated within the PSA. Because we used the precautionary approach of scoring an attribute as high risk if data were poor, this could result in an unnecessarily inflated risk for that particular species. This precautionary approach meant that ecological components were scored as high risk where relevant data were missing, resulting in a higher proportion of false positives (risk assessed to be high when it was really low), than false negatives (risk assessed to be low when it was actually high). However, uncertainty scores were applied and these were intended to inform decision makers about the level of uncertainty in vulnerability scores, and hence the possible targets of future research needs. (Hobday *et al.* 2007, Patrick *et al.* 2010).

### **2.4 Operational Objectives**

Operational objectives were discussed and determined during technical consultations held during the CRFM Scientific Meeting in 2011. Following the methodology of Hobday *et al.* (2007) operational objectives, or measurable endpoints, are expressed as the limits to acceptable change. The criteria for selecting operational objectives for risk assessments were that they must be:

1. Biologically Relevant
2. Have an unambiguous operational definition
3. Accessible to prediction and management
4. Quantities must be expressed as the hazards

Each component of the original ERAEF methodology (target, by-product, TEP, habitat and community) has relevant sub-components. Each operational objective is matched to a respective indicator.

For example:

1. Core objective = “What is the general goal”
2. Operational Objective = “What you are specifically trying to achieve”
3. Indicator = “What you are going to use to measure performance”
4. Rationale

### **2.5 Hazard Identification**

A hazard is an activity associated with fishing that has a direct or indirect negative effect on the ecosystem. Following the methodology of Hobday *et al.* (2007) hazards can be divided into six categories:

1. Capture
2. Direct impact without capture
3. Addition/Movement of Biological Material
4. Addition of Non-Biological Material
5. Disturbance of Physical Processes
6. External Hazards

These categories are further divided into sub-categories of fishing activities or external activities. The hazard identification analysis was completed by the Large Pelagic Working Group during the 2011 CRFM Scientific Meeting. To do this, each activity was scored on a presence/absence scale, i.e. ‘one’ if the activity does occur and ‘zero’ if the activity does not occur. The rationale for each score was also documented, based on technical consultations within the Working Group.

### **2.6 Level I: Scale Intensity Consequence Analysis (SICA) Aspects**

A SICA table for the target species were discussed and produced during the 2011 CRFM Scientific Meeting following the methodology of Hobday *et al.* (2007), which provided scoring guidelines for the

different components of the SICA analysis. In particular, the temporal and spatial scales of each identified hazard activity were rated according to the scoring guidelines provided in Table 2. The most appropriate sub-components from the Operational Objectives were chosen and the intensity and consequence of each identified hazard activity was then additionally rated according to scoring guidelines noted in Tables 3 and 4, also taken from Hobday *et al.* (2007). From this analysis, if anything scored a three or above on the consequence scale, further analyses were pursued at the Level two (PSA) stage.

Table 2: Spatial and temporal scale scoring table (Source: Hobday *et al.* 2007)

<b>Spatial Scale in Nautical Miles (nm)</b>	<b>Score</b>
<1 nm	1
1-10 nm	2
10-100 nm	3
100-500 nm	4
500-1000 nm	5
>1000 nm	6
<b>Temporal Scale in days</b>	<b>Score</b>
Decadal (once every 10 years or so)	1
Several Years (1 day every several years)	2
Annual (1-100 days per year)	3
Quarterly (100-200 days per year)	4
Weekly (200-300 days per year)	5
Daily (300-365 days per year)	6

Table 3: Intensity of fishing activities scoring table (Source: Hobday *et al.* 2007, modified from Fletcher *et al.* 2002)

<b>Level</b>	<b>Score</b>	<b>Description</b>
Negligible	1	Remote likelihood of detection at any spatial or temporal scale
Minor	2	Occurs rarely or in a few restricted locations and detectability even at these scales is rare
Moderate	3	Moderate at broader spatial scale, or severe but local
Major	4	Sever and occurs reasonably often at broad spatial scale
Severe	5	Occasional but very severe and localized or less severe but widespread and frequent
Catastrophic	6	Local to regional severity or continual and widespread

Table 4: Consequence of fishing activities scoring table (Source: Hobday *et al.* 2007, modified from Fletcher *et al.* 2002)

<b>Level</b>	<b>Score</b>	<b>Description</b>
Negligible	1	Impact unlikely to be detectable at the scale of stock/habitat/community
Minor	2	Minimal impact on stock/habitat/community structure or dynamics
Moderate	3	Maximum impact that still meets an objective (e.g. sustainable level of impact such as full exploitation rate for a target species).
Major	4	Wider and longer term impacts (e.g. long-term decline in CPUE)
Severe	5	Very serious impacts now occurring with relatively long time period likely to be needed to restore to an acceptable level (e.g. serious decline in spawning biomass limiting population increase)
Intolerable	6	Widespread and permanent/irreversible damage or loss will occur- unlikely to ever be fixed (e.g. extinction)

## 2.7 Level II: Productivity Susceptibility Analysis

This stage of the analysis, because it is semi-quantitative in nature, reduces the need for stakeholder engagement, as the analysis is focused on existing data, information and published knowledge. Considered a consultation stage with available information, the components identified at moderate or high risk at Level 1 (SICA) will be assessed at Level 2 (PSA). Web-based libraries (ICCAT database, www.fishbase.com, www.sealifebase.com, www.searoundus.com) as well as published scientific literature were consulted to infer biological and methodological information about productivity and susceptibility aspects of the species identified in the units of analysis. This information was then used to rank the species along two indexes indicating the sustainability of the species to being captured in the fishery. The first index, biological productivity (P), is defined as the capacity of the stock to rapidly recover once depleted, consists of seven attributes of species biology. The second index, susceptibility (S) to fishing pressures, is defined as the potential for the stock to be negatively impacted by the fishery. The values for P and S were determined by giving each species a score ranging from 1 to 3 for a selected set of attributes for each index listed and summarized below based on their relative biology and ecology (7 attributes for productivity and 3 attributes for susceptibility) (Table 5 and 6, respectively, taken from Hobday *et al.* 2007). A score of 1 on either axis suggests a species has low susceptibility to capture or a high capacity to recover (low risk); a score of 3 suggests the species is highly susceptible to capture or has a low capacity to recover (high risk). Depending on the criteria of the attributes, the scores were based on categorical (e.g. Batch Spawner versus Live Bearer for the attribute: Reproductive Strategy) or continuous data (e.g. under 5 versus over 25 for the attribute: maximum age). Where continuous data were used, suggesting there was no information available to assign divisions between the ranks, the range of the data was divided into thirds to create the categories. When data gaps for certain aspects of species occur, information was inferred from a related species for that particular attribute. When similar species information was not available or not logical to use in the absence of data, the species was given the highest vulnerability score according to the precautionary method. PSA was completed for both high and low volume target species.

### 2.7.1 Index 1: Productivity of a stock to rapidly recover once depleted

Individual species are scored according to the guidelines provided by Hobday *et al.* (2007).

Table 5: Index 1: Productivity scores of a stock to rapidly recover once depleted and guidelines for application of scores (Source: Hobday *et al.* 2007)

Attribute	Description	Low Productivity (high risk score = 3)	Med Productivity (med risk score = 2)	High Productivity (low risk score = 1)
Average age at maturity	Age at maturity is related to both natural mortality and maximum age. Longer lived, low productivity stocks will have a higher age at maturity, whereas a shorter lived, high productivity species will have a lower age at maturity.	>15 years	5-15 years	<5 years
Average max age	Maximum age is correlated with natural mortality through an inverse relationship. The longer the species lives, the slower the population tends to recover.	>25 years	10-25 years	<10 years
Fecundity	Fecundity varies with size and age of the spawner. Where data were	<100 eggs	100-20,000 eggs	>20,000 eggs

	not available, reproductive strategy provided a good proxy for relative fecundity.			
Average size at maturity	It usually takes a longer time for a species to reach maturity if it has a higher maximum size, therefore a lower productivity the larger the size at maturity.	>300 cm	100-300 cm	<100 cm
Average max size	Maximum size is correlated with productivity, as larger fish tend to live longer and have slower rates of recovery for the population and therefore, lower productivity.	>200 cm	40-200 cm	<40 cm
Reproductive strategy	Breeding strategy is correlated with natural mortality that may be expected within the first stages of the species life history. Species that are broadcast spawners generally have the capacity to produce more young at a higher frequency than species that bear live young. Therefore, broadcast spawners may have the capacity to recover more quickly if the population is depleted.	Live Bearer (and birds)	Demersal Egg Layer	Batch Spawner
Trophic Level	The level at which a stock exists on the food web within a community is an indicator of productivity. Usually, the lower the trophic level, the more productive a species tends to be.	>3.25	2.75-3.25	<2.75

## 2.7.2 Index 2: Susceptibility of the stock to be negatively impacted by the fishery

### 2.7.2.1 Availability

According to the method, we assumed that species with a range more restricted than the fishing area in focus is impacted more heavily by fishing effort than those with a broader range. Using general knowledge, broad scale distribution was recorded, and then cross-referenced against the possibility of local stocks or subpopulations due to distribution boundaries to adjust (stock structure proxy) scores. When little was known of the specific species distribution or the species was highly migratory (i.e. tunas), the score was based on the geographical area in which the species was commonly found. Species were classified into three categories with regard to availability: global if they ranged across multiple oceans; regional if they occurred in the Western Hemisphere only (Atlantic Ocean, Caribbean Sea, Mediterranean Ocean and Gulf of Mexico); and local if they were endemic to the study area.

### 2.7.2.2 Encounterability

#### *Spatial Encounterability*

Longlines and trolling lines were typically set in the upper portion of the water column. Hence, those species inhabiting this area, the epipelagic zone, were believed to be more vulnerable to encountering these types of fishing gear than those that were expected to occur in the mesopelagic or bathypelagic zones. This information was therefore used to guide the scoring for this attribute.

Selectivity

This attribute was scored based on the relative size of the animal with regard to the gear used. Upon consultation with fishery scientists and experts, it was agreed to use length frequency categories in the absence of expansive length at catch and regional hook selectivity information. Length frequencies were determined by creating frequency distribution graphs for those species with some length at catch information.

A ratio,  $S_{risk}$ , was developed to determine the risk score of various species with regard to selectivity. Using length at first maturity ( $L_m$ ) information and average length caught ( $L_{caught}$ ) of various species by hook and line gear we could determine whether the species is more at risk to be selected before maturity (highest risk) or after maturity (lowest risk).

$$S_{risk} = L_{caught} / L_m$$

The risk scores assigned from the ratio are as follows:  $>1$ = risk score of 1,  $\sim 1$ =score of 2,  $<1$ =score of 3.

Post Capture Mortality (PCM)

According to the ERAEF method, species are assumed to be killed on capture based on their fate, or role in the fishery unless there is credible scientific information that supports otherwise. In our study, PCM was removed from the susceptibility index as all targets were assumed to be retained and no observer data exist for TEP species.

Table 6: Index 2: Adapted Susceptibility scores and cut-offs of the stock to be negatively impacted by the fishery

Attribute	Sub-category	Rationale	Risk Scores		
			Low = 1	Med = 2	High = 3
Availability	Global Distribution	A species with a smaller global distribution may be more vulnerable to fishing pressures.	Global	Western Hemisphere only	Endemic to the Lesser Antilles
Encounterability	Water Column Depth	Longlines are set in the upper, epipelagic portion of the water column, so those species inhabiting this area are more vulnerable to encountering the fishing gear.	Bathy/Benthopelagic (>500m or located on the bottom)	Mesopelagic (200-500m)	Eipelagic (surface-200m)
Selectivity	Length Frequencies	Average length of fish caught ( $L_{caught}$ ) compared with the average length at maturity ( $L_m$ )	$L_{caught}/L_m > 1$	$L_{caught}/L_m = 1$	$L_{caught}/L_m < 1$

**2.8 Analysis of criteria**

The scores for each of the attributes were then combined to obtain an overall productivity and susceptibility score. Smith *et al.* 2007 suggests using the arithmetic mean of the productivity attributes and the geometric mean of the susceptibility attributes to be combined and graphically represented on an X-Y scatter plot. The overall vulnerability (V) could then be determined by estimating the Euclidian distance to the point of origin using the following formula:

$$\text{Euclidean distance } \{(P,S), (X0,Y0)\} = \sqrt{[(P-X0)^2 + (S-Y0)^2]}$$

Where  $X0$  and  $Y0$  are the (x, y) origin coordinates, respectively.



The original format, adopted from Walker (2004) employed a method of analysis using an additive approach to susceptibility scores. This resulted in high-risk scores for species that were never caught. The solution adapted by Hobday *et al.* 2007 was to use a multiplicative approach of susceptibility scores from the independent aspects, which we adopted for the purpose of the present study.

Species with high susceptibility and low productivity are considered the most at risk for overfishing, whereas those with a low susceptibility and high productivity are considered the least vulnerable. Since the overall “risk” of vulnerability to fishing pressures determined from the PSA analysis was based on intrinsic values of the attributes, the scores do not reflect past or future fishing effort, nor population size (Cotter and Lart 2011). Using these attributes and the multiplicative approach still does not result in a measure of absolute risk. This is because there is no measure taken for actual mortality, nor its abundance or sustainable removal rate. These are taken into consideration at Level 3.

### 3. RESULTS

#### 3.1 Scoping

##### 3.1.1 Species Lists

After assessing the three species lists generated, there was a total of 23 species identified as high-priority targets (TA1), 16 species identified as low-priority targets (TA2) and 65 species identified as Threatened, Endangered or Protected species (TEP) (Table 7).

Table 7: Units of Analysis List: high priority target species (TA1); low priority target species (TA2); threatened, endangered or protected species (TEP).

Role	Species Name	Common Name	Taxa
TA1	<i>Acanthocybium solandri</i>	Wahoo	Teleost
TA1	<i>Auxis thazard</i>	Frigate Tuna	Teleost
TA1	<i>Barracuda spp.</i>	Barracuda	Teleost
TA1	<i>Carcharhinus leucas</i>	Bull shark	Chondrichthyan
TA1	<i>Carcharhinus perezi</i>	Caribbean Reef Shark	Chondrichthyan
TA1	<i>Coryphaena hippurus</i>	Dolphin	Teleost
TA1	<i>Elagatis bipinnulatus</i>	Salmon/RR	Teleost
TA1	<i>Euthynnus alleteratus</i>	Little Tunny	Teleost
TA1	<i>Istiophorus albicans</i>	Sailfish	Teleost
TA1	<i>Katsuwonus pelamis</i>	Skipjack	Teleost
TA1	<i>Makaira nigricans</i>	Blue Marlin	Teleost
TA1	<i>Mustelus higmani</i>	Smalleye smooth-hound shark	Chondrichthyan
TA1	<i>Mustelus canis</i>	Dusky smooth-hound shark	Chondrichthyan
TA1	<i>Sarda sarda</i>	Bonito	Teleost
TA1	<i>Scomberomorus cavalla</i>	King Mackerel	Teleost
TA1	<i>Scomberomorus brasiliensis</i>	Spanish Mackerel	Teleost
TA1	<i>Squalus cubanesis</i>	Dogfish Sharks	Chondrichthyan
TA1	<i>Tetrapturus albidus</i>	White Marlin	Teleost
TA1	<i>Thunnus alalunga</i>	Albacore tuna	Teleost
TA1	<i>Thunnus albacares</i>	Yellowfin tuna	Teleost
TA1	<i>Thunnus atlanticus</i>	Blackfin tuna	Teleost
TA1	<i>Thunnus obesus</i>	Bigeye tuna	Teleost
TA1	<i>Xiphias gladius</i>	Swordfish	Teleost
TA2	<i>Caranx lugubris</i>	Black Jack	Teleost
TA2	<i>Carcharhinus brevipinna</i>	Spinner shark	Chondrichthyan
TA2	<i>Carcharhinus falcifer</i>	Silky shark	Chondrichthyan

TA2	<i>Carcharhinus limbatus</i>	Black-tip Shark	Chondrichthyan
TA2	<i>Coryphaena equiselis</i>	Pompano dolphinfish	Teleost
TA2	<i>Galeocerdo cuvier</i>	Tiger Shark	Chondrichthyan
TA2	<i>Ginglymostoma cirratum</i>	Nurse Shark	Chondrichthyan
TA2/TEP	<i>Globicephala macrorhynchus</i>	Short-finned Pilot Whale	Marine Mammal
TA2	<i>Isurus oxyrinchus</i>	Short-fin Mako	Chondrichthyan
TA2	<i>Negaprion brevirostris</i>	Lemon Shark	Chondrichthyan
TA2	<i>Prionace glauca</i>	Blue Shark	Chondrichthyan
TA2	<i>Scomberomorus regalis</i>	Cero Mackerel	Teleost
TA2/TEP	<i>Sphyrna lewini</i>	Scalloped Hammerhead	Chondrichthyan
TA2/TEP	<i>Sphyrna mokarran</i>	Great hammerhead	Chondrichthyan
TA2	<i>Tursiops truncatus</i>	Common bottlenose dolphin	Marine Mammal
TA2	<i>Alopias vulpinus</i>	Thresher shark	Chondrichthyan
TEP	<i>Balaenoptera physalus</i>	Fin whale	Marine Mammal
TEP	<i>Megaptera novaeangliae</i>	Humpback whale	Marine Mammal
TEP	<i>Physeter macrocephalus</i>	Sperm Whale	Marine Mammal
TEP	<i>Kogia breviceps</i>	Pygmy Sperm Whale	Marine Mammal
TEP	<i>Kogia simus</i>	Dwarf Sperm Whale	Marine Mammal
TEP	<i>Orcinus orca</i>	Killer whale	Marine Mammal
TEP	<i>Pseudorca crassidens</i>	False killer whale	Marine Mammal
TEP	<i>Delphinus delphis</i>	Common dolphin	Marine Mammal
TEP	<i>Balaenoptera acutorostrata</i>	Common Minke Whale	Marine Mammal
TEP	<i>Balaenoptera borealis</i>	Sei Whale	Marine Mammal
TEP	<i>Balaenoptera edeni</i>	Bryde's Whale	Marine Mammal
TEP	<i>Feresa attenuata</i>	Pygmy Killer Whale	Marine Mammal
TEP	<i>Mesoplodon mirus</i>	True's beaked whale	Marine Mammal
TEP	<i>Globicephala melas</i>	Long-finned Pilot Whale	Marine Mammal
TEP	<i>Grampus griseus</i>	Risso's Dolphin	Marine Mammal
TEP	<i>Lagenodelphis hosei</i>	Fraser's Dolphin	Marine Mammal
TEP	<i>Stenella coeruleoalba</i>	Striped Dolphin	Marine Mammal
TEP	<i>Stenella longirostris</i>	Long-snouted Spinner Dolphin	Marine Mammal
TEP	<i>Steno bredanensis</i>	Rough-toothed Dolphin	Marine Mammal
TEP	<i>Tursiops truncatus</i>	Bottlenose Dolphin	Marine Mammal
TEP	<i>Delphinus capensis</i>	Long-beaked common dolphin	Marine Mammal
TEP	<i>Carcharhinus longimanus</i>	Oceanic Whitetip Shark	Chondrichthyan
TEP	<i>Carcharias taurus</i>	Grey nurse shark	Chondrichthyan
TEP	<i>Carcharhinus obscurus</i>	Dusky shark	Chondrichthyan
TEP	<i>Carcharhinus signatus</i>	Night shark	Chondrichthyan
TEP	<i>Carcharodon carcharias</i>	(Great) White shark	Chondrichthyan
TEP	<i>Caretta caretta</i>	Loggerhead turtle	Marine Reptile
TEP	<i>Centrophorus granulosus</i>	Gulper shark	Chondrichthyan
TEP	<i>Chelonia mydas</i>	Green Turtle	Marine Reptile
TEP	<i>Dermochelys coriacea</i>	Leatherback turtle	Marine Reptile
TEP	<i>Eretmochelys imbricata</i>	Hawksbill Turtle	Marine Reptile
TEP	<i>Isurus paucus</i>	Long-fin Mako	Chondrichthyan
TEP	<i>Lepidochelys olivacea</i>	Olive ridley turtle	Marine reptile
TEP	<i>Manta birostris</i>	Giant oceanic manta ray	Chondrichthyan

TEP	<i>Mustelus canis</i>	Dusky Smoothhound	Chondrichthyan
TEP	<i>Pristis pectinata</i>	Smalltooth sawfish	Chondrichthyan
TEP	<i>Pristis perotteti</i>	Large-tooth sawfish	Chondrichthyan
TEP	<i>Rhincodon typus</i>	Whale shark	Chondrichthyan
TEP	<i>Sphyrna zygaena</i>	Smooth hammerhead	Chondrichthyan
TEP	<i>Trichechus manatus</i>	West Indian Manatee	Marine Mammal
TEP	<i>Fregata magnificens</i>	Magnificent Frigatebird	Marine Bird
TEP	<i>Anous minutus</i>	Black Noddy	Marine Bird
TEP	<i>Sterna anaethetus</i>	Bridled tern	Marine Bird
TEP	<i>Sterna bengalensis</i>	Lessercrowned tern	Marine Bird
TEP	<i>Sterna caspia</i>	Caspian tern	Marine Bird
TEP	<i>Sterna dougallii</i>	Roseate tern	Marine Bird
TEP	<i>Sterna fuscata</i>	Sooty tern	Marine Bird
TEP	<i>Sterna hirundo</i>	Common tern	Marine Bird
TEP	<i>Gelochelidon nilotica</i>	Gull-billed tern	Marine Bird
TEP	<i>Pelecanus occidentalis</i>	Brown pelican	Marine Bird
TEP	<i>Phaethon aethereus</i>	Red billed tropicbird	Marine Bird
TEP	<i>Phaethon lepturus</i>	White tailed tropicbird	Marine Bird
TEP	<i>Pterodroma hasitata</i>	Black capped petrel	Marine Bird
TEP	<i>Puffinus assimilis</i>	Little shearwater	Marine Bird
TEP	<i>Puffinus gravis</i>	Great shearwater	Marine Bird
TEP	<i>Puffinus lherminieri</i>	Audubon's shearwater	Marine Bird
TEP	<i>Puffinus carneipes</i>	Flesh-footed Shearwater	Marine Bird
TEP	<i>Puffinus griseus</i>	Sooty Shearwater	Marine Bird
TEP	<i>Puffinus bulleri</i>	Buller's Shearwater	Marine Bird
TEP	<i>Sula dactylatra</i>	Atlantic masked Booby	Marine Bird
TEP	<i>Sula leucogaster</i>	Brown Booby	Marine Bird
TEP	<i>Sula sula</i>	Red footed booby	Marine Bird

### 3.2 Operational Objectives

The Core Objectives for management and operational objectives (sub-components), with the latter expressed as limits to acceptable change (or endpoints) identify what you are trying to achieve and are stated in ways that can be measured. Table 8 shows a preliminary set of objectives considered useful for the fishery for each of the species components (target and TEP species). In some cases, defined limits were not specified, as these needed to be confirmed through further stakeholder consultations.

Table 8: Operational objectives, or measurable endpoints, are expressed as the limits to acceptable change.

Component	Core Objective	Sub-Component	Example of Operational Objective	Example of Indicator (measure of performance)
Target Species	Avoid recruitment failure Avoid negative consequences for species or population sub-components	1. Population size	1.1 No trend in biomass	Biomass, numbers, density, CPUE, yield
			1.2 Maintain biomass above a specified level	
			1.3 Maintain catch at a specified level	
			1.4 Species do not approach extinction or become extinct	

		2. Geographic range	2.1 Geographic range of the population, in terms of size and continuity does not change outside acceptable bounds	Presence of population across space
		3. Genetic structure	3.1 Genetic diversity does not change outside acceptable bounds	Frequency of genotypes in the population, effective population size, number of spawning units
		4. Age/size/sex structure	4.1 Age/size/sex structure does not change outside acceptable bounds (e.g. more than X% from reference structure)	Biomass numbers of relative proportion in age/size/sex classes Biomass of spawners Mean size, sex ratio
		5. Reproductive Capacity	5.1. Fecundity of the population does not change outside acceptable bounds (e.g. more than X% of reference population fecundity) 5.2. Recruitment to the population does not change outside acceptable bounds	Egg production of population Abundance of recruits
		6. Behavior/ Movement	6.1 Behaviour and movement pattern of the population do not change outside acceptable bounds	Presence of population across space, movement patterns within the population (e.g. attraction to bait, lights)
TEP species	Avoid recruitment failure of TEP species Avoid negative consequences for TEP species or population sub-components Avoid negative impacts on the population from fishing	1. Population size	1.1 No trend in biomass	Biomass, numbers, density, CPUE, yield
			1.2 Maintain biomass above a specified level	
			1.3 Maintain catch at a specified level	
			1.4 Species do not further approach extinction or become extinct	
		2. Geographic range	2.1 Geographic range of the population, in terms of size and continuity does not change outside acceptable bounds	Presence of population across space
		3. Genetic structure	3.1 Genetic diversity does not change outside acceptable bounds	Frequency of genotypes in the population, effective population size, number of spawning units
		4. Age/size/sex structure	4.1 Age/size/sex structure does not change outside acceptable bounds (e.g. more than X% from reference structure)	Biomass numbers of relative proportion in age/size/sex classes Biomass of spawners Mean size, sex ratio

		5. Reproductive Capacity	5.1. Fecundity of the population does not change outside acceptable bounds (e.g. more than X% of reference population fecundity) 5.2. Recruitment to the population does not change outside acceptable bounds	Egg production of population Abundance of recruits
		6. Behaviour/ Movement	6.1 Behaviour and movement pattern of the population do not change outside acceptable bounds	Presence of population across space, movement patterns within the population (e.g. attraction to bait, lights)
		7. Interactions with fishery	7.1 Survival after interactions is maximized 7.2 Interactions do not affect the viability of the population or its ability to recover	Survival rate of species after interactions Number of interactions, biomass or numbers in population

### 3.3 Hazard Identification

A number of hazards (fishing activities) were eliminated at Level 1 (Table 9). Those remaining included:

- Fishing (impacted species with both capture and without capture and through disturbing physical processes)
- Bait collection (impacted species with both capture and without capture and through disturbing physical processes)
- Incidental Behaviour (impacted those species caught)
- Gear loss (impacted species with both capture and without capture and through the addition of non-biological material)
- Navigation/steaming (impacted species without direct capture and through the addition of non-biological material and through disturbing physical processes)
- On-board processing (impact through the addition/movement of biological material)
- Provisioning (impact through the addition/movement of biological material)
- Organic Waste Disposal (impact through the addition/movement of biological material)
- Debris (impact through the addition on non-biological material)
- Chemical Pollution (impact through the addition on non-biological material)
- Exhaust (impact through the addition on non-biological material)
- Activity/presence on water (impact through the addition of non-biological material)
- Anchoring/mooring (impact through the disturbance of physical processes)
- Other Fisheries (external impacts)
- Other extractive activities (external impacts)
- Other non-extractive activities (external impacts)
- Other anthropogenic activities (external impacts)

Table 9: Results of hazard identification exercise, indicating the presence/absence of various hazard activities identified in the Eastern Caribbean large pelagic fishery, with emphasis on dolphinfish, and providing the rationale for these identifications.

Direct impact of fishing	Fishing activity	Presence (1) Absence (0)	Rationale
Capture	Bait collection	1	The handlines/troll lines hooks are baited with fresh bait prior to the gear being deployed into the waters. Bait is normally fished from the same vessel and potentially during the same trip when fishing for dolphinfish. Preferred bait species include: flyingfish, ballyhoo, bonito, skipjack tuna and jacks (generally use 1 Flyingfish and 1 ballyhoo for 1 dolphinfish unless the dolphinfish appear to be hungry and actively feeding, in which case the bait is cut up into pieces. A 5-6lb tuna would serve as bait to catch ~16-22 dolphinfish)
	Fishing	1	Capture of dolphinfish by deployment and retrieval of hand line/troll lines, artisanal long lines, gillnets as well as byproduct and potentially TEP species
	Incidental behaviour	1	During down time (rests between fishing periods), crew may throw their own lines into water for personal catches. Also, some crew may gaff other upon return from fishing grounds
Direct impact without capture	Bait collection	1	Disorientation/mortality/injury as a result of gear deployment and retrieval methods of gillnets/dip nets may occur. Indirect effects of prey food removal on target/byproduct species.
	Fishing	1	Disorientation/mortality/injury as a result of gear deployment and retrieval methods for the dolphinfish fishery (e.g. Sea birds and sea turtles may occasionally get caught in the fishing gear (some fishermen claimed that they've seen fishers actively damage sea birds because they'll try to eat their catch), and will cut fishing lines, especially if taken by oceanic sharks).
	Incidental behaviour	0	Not applicable
	Gear loss	1	Loss of hooks and lines. Potential negative impact on species such as large pelagics, small cetaceans, sea turtles, sharks, e.g. wahoo have sharp teeth that easily cut the line, the hooks may potentially be swallowed)
	Anchoring/mooring	0	Boats do not anchor while fishing for dolphinfish and other large pelagic species. Some vessels will moor using a rope, chain and buoy on sandy bottoms that do not impact organisms
	Navigation/steaming	1	Navigation and steaming to find aggregations of dolphinfish and other large pelagics may result in disorientation/mortality/injury with pelagic organisms upon rare occasion
Addition/movement of	Translocation of species	0	Not practiced.

biological material	On board processing	1	Onboard processing occurs in several countries within the region. For example: sharks are headed and gutted, but fins and trunks are retained; billfish are headed, finned, and gutted; tunas, wahoo and dolphinfish, rainbow runner, swordfish, and barracuda can also be processed on board, and unused bits are tossed overboard).
	Discarding catch	0	Damaged fish that can no longer be used will rarely be discarded. Generally everything that is caught is either landed or used for bait including juvenile fish.
	Stock enhancement	0	Not practiced.
	Provisioning	1	Fresh baited hooks are used. Generally fished for during the same trip therefore movement of biological material may be considered minimal.
	Organic waste disposal	1	Disposal of organic wastes (food scraps and sewage, depending of vessel) as a result of general fishing vessel operations.
Addition of non-biological material	Debris	1	Food packaging (especially drink bottles), plastics and almost all garbage are frequently thrown overboard. The debris generated during general vessel operations may result in damage/mortality/ disorientation of organisms. Fishers may toss their own handmade FADs into the water in order to increase their catch which is believed to influence the behaviour of the fish.
	Chemical pollution	1	Small amounts of diesel/oil may be introduced into the water by boat pumps or drain valves. Termite repellent used to spray boats may be introduced to the water. Detergents are used to wash clothes when fishermen are at sea, and these would be introduced into the water.
	Exhaust	1	Exhaust from diesel engines occurs during navigation and steaming.
	Gear loss	1	Hook and lines may be lost as a result of large fish bursting the lines (hook is potentially swallowed by the fish). Damaged hooks and lines will often get thrown overboard by fishers. Ghost fishing may result in entanglement, causing damage/mortality/ disorientation of organisms. Lost gear in the net fisheries may result in habitat damage, as well as ghost fishing.
	Navigation/steaming	1	Navigation and steaming to and from fishing grounds may introduce noise and visual stimuli into the environment. Boat collision and sinking can occur, as well as echo sounding.
	Activity/presence on water	1	Presence of fishing vessels on the fishing grounds may introduce noise and visual stimuli to the environment which may attract foraging animals. Loss of activities occurs on deck at the fishing grounds, e.g. communication between fishers/crews regarding gear deployment, and fishing operations.
Disturb physical	Bait collection	1	Gill net and dip net fishing activities may disturb/disrupt local physical water flow patterns, e.g. vertical mixing

processes	Fishing	1	The use of FADs, troll lines and handlines may disturb physical processes in the localized area and /or disrupt <i>Sargassum</i> flows as a result of fishing activities
	Boat launching	1	Some fishing boats (e.g. small pirogues) launch from beach
	Anchoring/ mooring	1	Some vessels will moor using a rope, chain and buoy on sandy bottoms which may influence physical processes in the local area
	Navigation/ steaming	1	Navigation to and from fishing grounds while trolling may disturb physical pelagic processes (e.g. mixed layer depth)
External Impacts (specify the particular example within each activity area)	Other fisheries	1	Overlap with purse seine, gill net, dip net and trawling fisheries
	Aquaculture	0	Not practiced.
	Coastal development	0	It is an offshore fishery
	Other extractive activities	1	Seismic surveying for petroleum, drilling, construction of pipelines, oil petroleum and gas.
	Other non extractive activities	1	Shipping lanes, cables
	Other anthropogenic activities	1	Cruise ships, drug smuggling (boats are very fast and can cut lines due to speed. In this regard also, fishermen safety is a concern)



### **3.4 Scale Intensity and Consequence Analysis (SICA)**

Among the hazards identified as being present, the associated risks rated as moderate/major (consequence scores of 3 or above) were all related to direct or indirect impacts from primary fishing operations including:

- Fishing (with or without direct capture)
- On-board processing
- Addition of debris
- Other Fisheries
- Other extractive activities

Table 10 provides further details of the SICA evaluation.

Table 10: SICA results for large pelagic species of interest in this study. Using the presence/absence scores developed from the Hazard ID table, the temporal and spatial scales of each activity were rated for the fishery and these are indicated here. The most appropriate sub-components from the Operational Objectives were also chosen and the intensity and consequence in relation to these objectives for the pelagic fishery were scored, as indicated.

Direct impact of fishing	Fishing activity	Presence (1) Absence (0)	Spatial scale	Temporal Scale	Unit of analysis	Sub-component	Operational objective	Intensity Score	Consequence score	Rationale
Capture	Bait collection	1	5	5	Pelagic species	Population size	6.1	3	1	Bait collection occurs daily over a 9-month season from Nov-Jul. Small tunas may get caught up in nets and landed. Intensity would be considered moderate at a broader spatial scale. Consequence is considered negligible because byproduct rarely gets caught up in nets.
	Fishing	1	3	5	Pelagic species	Population size	1.2	4	3 to 4	Fishing occurs daily over a 9 month season from Nov-Jul. May influence population size of the stock. Intensity of the fishing activity is widespread and frequent. Consequence is considered moderate- the use of FADs during fishing may target specific fish within the population (i.e. juveniles and females).
	Incidental behaviour	1	3	5	Pelagic species	Population size	1.2	2	1	On down time crew may throw their own lines into water for personal catches. Recreational activities by fishers are believed have negligible impact on the byproduct
Direct impact without capture	Bait collection	1	5	5	Pelagic species	Behaviour/ Movement	6.1	3	1	Bait collection occurs daily over a 9-month season from Nov-Jul. Local depletion of baitfish most likely to impact behaviour/movement of byproduct species, and fishers will search elsewhere for baitfish. Intensity would be considered moderate at a broader spatial scale. Consequence is considered negligible because baitfish species (e.g. flyingfish) fluctuate with no specific trend.
	Fishing	1	0	0	Pelagic species	Behaviour/ Movement	6.1	4	3 to 4	Higher trophic level predators increase in numbers as they are attracted to bait, and may take fish on/near hooks. That is to say, use of FADs attracts higher level predators. Catchability increases generally around the FADs, impacting the behaviour/movement of the billfish. Intensity is considered localized and moderate. Consequence is considered moderate.

	Incidental behaviour									
	Gear loss	1	0	0	Pelagic species	Population size	6.1	3	2	Loss of hooks and lines occur over the entire fishing area. Intensity considered major to severe because gear loss often happens daily over a broad spatial scale. Wahoo have sharp teeth and often burst lines when feeding on bait. This event may interfere with future feeding by fish, and fish may become entangled in the lines. Consequence is considered to be minor because minimal influence on the population.
	Anchoring/mooring									
	Navigation/steaming	1	0	0	Pelagic species	Behaviour/Movement	1.2	3	2	Interactions with pelagic species may occur which would likely influence behaviour. Intensity is moderate over a broad spatial scale. Consequence is considered minor, although change in behaviour from this activity would be difficult to measure in practice.
Addition/movement of biological material	Translocation of species	0	5	5						
	On board processing	1	5	1	Pelagic species	Behaviour/Movement	6.1	3	3	Onboard processing of all landed fish species may occur throughout the entire fishing area. The extent to which byproduct species are attracted to or feed on the material is unknown. However, this activity is not believed to have measurable effects on the behaviour of byproduct species, effect could be more significant for TEP species, because of attraction of shark species. Hence score of 3 is indicated in respect of TEP species
	Discarding catch	1	0	0	Pelagic species	Population size	1.2	3	2	Discarding of catch is virtually non-existent in this multi-species fishery and generally everything that is caught is either landed, or used for bait (including juvenile fish). Rarely, damaged (devalued) fish by predation are discarded. Intensity is considered negligible due to the remote likelihood of detection at any spatial or temporal scale. Consequence is also negligible because discarding almost never occurs.
	Stock enhancement									
	Provisioning	1	5	5	Pelagic species	Population size	1.2	3	2	Higher predator numbers increase through introduction of bait and may impact the number of fish injured/taken by predators. Intensity is considered localized but moderate. Consequence is

									considered minor.	
	Organic waste disposal	1	5	5	Pelagic species	Behaviour/ Movement	6.1	2	1	Disposal of organic wastes (food scraps, and sewage, depending of vessel) as a result of general fishing vessel operations. Most likely to affect behaviour/movement as a result of attraction to waste. Intensity is considered minor because although disposal occurs, the daily volume is very small. Consequence is negligible because it is unlikely for interactions to occur.
Addition of non-biological material	Debris	1	5	3	Pelagic species	Behaviour/ Movement	6.1	2	3	Food packaging (mostly drink bottles), plastics and almost all garbage are frequently thrown overboard. These most likely affect the behaviour/movement of byproduct species because they may aggregate around floating objects. Intensity considered minor because small amounts are lost overboard, everyday, over a large spatial scale. Consequence to behaviour/movement is considered minor, though turtles are known to ingest the food packaging. Hence, score of 3 is allocated to be precautionary in respect of turtles.
	Chemical pollution	1	5	5	Pelagic species	Population size	1.2	1	1	Small amounts of diesel/oil may be introduced into the water by boat pumps or drain valves. Termite repellent used to spray boats may be introduced to the water. Detergents used to wash clothes when fishermen are at sea. Intensity is considered negligible because of the remote likelihood of detection at a spatial and temporal scale. Consequence is considered negligible because unlikely that interactions are occurring between chemicals.
	Exhaust	1	5	5	Pelagic species	Behaviour/ Movement	6.1	1	1	Fishing activity and hence exhaust emissions occur throughout the entire fishing area. Intensity is considered negligible because although hazard was considered over a large range/scale, exhaust impacts believed to occur on a small scale. Consequence is considered negligible because unlikely to change fish behaviour in a permanent way.
	Gear loss	1	5	3 - 5	Pelagic species	Population size	6.1	4-5	2	Loss of hooks and lines occur over the entire fishing area. Intensity is considered major to severe because gear loss often happens daily over a broad spatial scale. Wahoo have sharp teeth and often burst lines when feeding on bait. This may interfere with future feeding, and fish could become entangled in the lines. Still consequence is considered to be minor in respect of population size.

	Navigation/ steaming	1	5	3 - 5	Pelagics	Behaviour/ Movement	6.1	3	2	Interactions with pelagic species may occur which would likely affect behaviour. Intensity is moderate over a broad spatial scale. Consequence is minor because unlikely to detect change in behaviour, but not likely to affect behaviour in a permanent way.
	Activity/ presence on water	1	3	5	Pelagic species	Behaviour/ Movement	6.1	2	2	Interactions with pelagic species may occur which would likely affect their behaviour/movement. Presence of fishing vessels introduces noise and visual stimuli which may affect behaviour of fish. Fish may aggregate around the floating vessel at the fishing grounds. Intensity is moderate over a broad spatial scale. Consequence is considered minor as the effect on fish behaviour is not likely to be permanent.
Disturb physical processes	Bait collection	1	5	5	Pelagic species	Behaviour/ Movement	6.1	1	1	Disturbance of physical processes due to gill net/dip net fishing may alter behaviour byproduct (e.g. momentary disruption to feeding/movement). Intensity is negligible because area impacted would be small. Consequence is also negligible because unlikely to significantly affect any behavioural change.
	Fishing	1	2	5	Pelagic species	Behaviour/ Movement	6.1	1	1	Disturbance of physical processes due to trolling and hand-line may alter behaviour of byproduct (e.g. momentary disruption to feeding/movement). Intensity is negligible because area impacted would be small (surface lines). Consequence is also negligible because unlikely to significantly affect any behavioural change.
	Boat launching	1	2	5	Pelagic species	Behaviour/ Movement	6.1	1	1	Some vessels will launch and haul out on the beach, which may disturb sediments. Intensity is considered small because although launching occurs in many countries, the actual area affected would be small. Consequence is considered negligible because large pelagic species do not occur in boat launching areas.
	Anchoring/ mooring	1	5	5	Pelagic species	Behaviour/ Movement	6.1	1	1	Anchoring does not occur at fishing grounds. Some vessels will moor using a rope, chain and buoy on sandy bottoms, which may influence physical processes in the local area and disturb sediments. Intensity is small because the actual area affected would be small. Consequence is believed to be negligible for large pelagic species that usually stay in open water column.
	Navigation/ steaming	1	4	5	Pelagic species	Behaviour/ Movement	6.1	1	1	Navigation to and from fishing grounds while trolling may disturb physical pelagic processes (e.g. mix surface layer) Intensity is negligible because area impacted would be small (mostly surface lines used). Consequence is considered negligible because unlikely to cause any permanent behavioural change.

External Impacts (specify the particular example within each activity area)	Other fisheries	1	0	0	Pelagic species	Population size	1.2	4-5	3	Because tunas are considered to be highly migratory species there is overlap of many fisheries within the region (gillnets/dip nets/purse seine/trawling/commercial). Overlap occurs reasonably often over a broad spatial scale. Consequence is considered moderate, with regard to effects on population size/growth rate
	Aquaculture									
	Coastal development									
	Other extractive activities	1	3	3	Pelagic species	Behaviour/Movement	6.1	3	3	Seismic surveying for petroleum, drilling, construction of pipelines, oil petroleum and gas exploration occur within the region which may affect byproduct behaviour/movement. Intensity of these activities occurs moderately at a broad spatial scale. Consequence is considered moderate because there is anecdotal information on possible detectable change in behaviour/movement but minimal impact on population dynamics.
	Other non extractive activities	1	5	6	Pelagic species	Behaviour/Movement	6.1	3	2	Moderate shipping activities occur throughout region. However it is likely to have a minor consequence on the behaviour/movement of byproducts. The effects of cables on the behaviour and movement are less predictable and uncertain.
Other anthropogenic activities	1	0	0	Pelagic species	Population size	1.2	3	2	Fishermen will avoid fishing in certain areas and during specific times of the day as a result of the drug smuggling activities (e.g. at night no fishing), even the rich fishing grounds and routes that the drug smugglers are taking. The possible consequence is considered minor to moderate with regard to population size effects.	

### 3.5 Productivity and Susceptibility Analysis (PSA)

Tables 11 and 12 show the results of the PSA for the two groups of species assessed based on their respective role in the fishery (high and low priority targets). These assessments measure direct impacts from fishing in accordance to the operational objective of avoiding overexploitation of a species due to fishing. The risk score assigned to each species is based on potential rather than actual risk. Thus some species could be assessed at high risk because they have low productivity and are exposed to the fishery, even though they are rarely, if ever, caught. The PSA method is likely to generate more false positives (assessing a species as high risk when it is actually low risk) than false negatives due to its precautionary approach to uncertainty, because attributes are set as high risk where information is not available.

Table 11: PSA results for high volume target species for the pelagic hook and line fishery, showing vulnerability/score categorization and value as follows: high (>3.18), medium (2.64-3.18), low (<2.64).

Scientific Name	Common Name	Role in Fishery	Landed weight (tonnes) form 2000-2011	Missing >3 attributes	Number of missing productivity attributes	Number of missing Susceptibility attributes	Productivity	Susceptibility	2D vulnerability value	Vulnerability Category
<i>Acanthocybium solandri</i>	Wahoo	TA1	4044.0	N	0	0	1.57	1.50	2.17	Low
<i>Auxis thazard</i>	Frigate mackerel	TA1	665.4	N	0	0	1.29	1.67	2.10	Low
<i>Carcharhinus leucas</i>	Bull Shark	TA1	228.6 (mixed group)	N	0	0	2.57	1.50	2.98	Med
<i>Carcharhinus perezii</i>	Caribbean Reef Shark	TA1		N	0	0	2.14	2.00	2.93	Med
<i>Coryphaena hippurus</i>	Dolphin Fish	TA1	13840.5	N	0	0	1.43	1.17	1.84	Low
<i>Elagatis bipinnulatus</i>	Rainbow runner	TA1	204.6	N	0	0	1.57	1.33	2.06	Low
<i>Euthynnus alleteratus</i>	Little Tunny	TA1	118.1	N	0	0	1.57	1.33	2.06	Low
<i>Istiophorus albicans</i>	Sailfish	TA1	2545.8	N	0	0	1.86	2.00	2.73	Med
<i>Katsuwonus pelamis</i>	Skipjack Tuna	TA1	3186.4	N	0	0	1.57	1.67	2.29	Low
<i>Makaira nigricans</i>	Blue marlin	TA1	2003	N	0	0	2.00	1.50	2.50	Low
<i>Mustelus canis</i>	Dusky smoothhound shark	TA1	2117.0	N	0	0	2.14	1.67	2.71	Med
<i>Mustelus higmani</i>	Smalleye smoothhound shark	TA1		N	0	0	2.00	2.00	2.83	Med
<i>Sarda sarda</i>	Bonito	TA1	1441.2	N	0	0	1.29	1.33	1.85	Low
<i>Scomberomorus cavalla</i>	King mackerel	TA1	8835.5	N	0	0	1.71	2.00	2.63	Low
<i>Scomberomorus brasiliensis</i>	Spanish mackerel	TA1	19162	N	0	0	1.43	1.67	2.20	Low
<i>Sphyraena barracuda</i>	Great Barracuda	TA1	77	N	0	0	1.71	1.33	2.17	Low

<i>Squalus cubanesis</i>	Cuban Dogfish shark	TA1	196.0	N	0	0	2.43	2.00	3.15	Med
<i>Tetrapturus albidus</i>	White marlin	TA1	343.3	N	0	0	1.71	1.50	2.28	Low
<i>Thunnus alalunga</i>	Albacore	TA1	670.2	N	0	0	1.86	2.00	2.73	Med
<i>Thunnus albacares</i>	Yellowfin Tuna	TA1	16587.3	N	0	0	1.57	1.33	2.06	Low
<i>Thunnus atlanticus</i>	Blackfin tuna	TA1	5270.2	N	0	0	1.43	1.67	2.20	Low
<i>Thunnus obesus</i>	Bigeye Tuna	TA1	498.8	N	0	0	1.71	1.50	2.28	Low
<i>Xiphias gladius</i>	Broad Billed Swordfish	TA1	1503.9	N	0	0	2.00	2.00	2.83	Med

Table 12: PSA results for low volume target species taken in the pelagic hook and line fishery, showing vulnerability score categorization and value as follows: high (>3.18), medium (2.64-3.18), low (<2.64). Vulnerability Scores with an asterisk (\*) next to them indicate a species that scored “Medium” for its vulnerability score, but was very close to scoring in the “High” category.

Scientific Name	Common Name	Role in Fishery	Landed weight (tonnes) form 2000-2011	Missing >3 attributes	Number of missing productivity attributes	Number of missing Susceptibility attributes	Productivity	Susceptibility	2D vulnerability value	Vulnerability Category
<i>Alopias vulpinus</i>	Thresher shark	TA2	34.0	N	0	0	2.71	1.50	2.95	Med
<i>Caranx lugubris</i>	Black jack	TA2	0.2	N	0	0	1.43	1.50	1.95	Low
<i>Carcharhinus brevipinna</i>	Spinner shark	TA2	81.0	N	0	0	2.43	1.50	2.85	Med
<i>Carcharhinus falciformis</i>	Silky Shark	TA2	6.5	N	0	0	2.57	1.33	2.85	Med
<i>Carcharhinus limbatus</i>	Black-tip shark	TA2	0.9	N	0	0	2.29	1.50	2.73	Med
<i>Carcharias taurus</i>	grey nurse shark	TA2	28.5	N	0	0	2.57	1.50	2.90	Med
<i>Coryphaena equiselis</i>	Pompano dolphinfish	TA2	15.0	N	0	0	1.43	1.17	1.84	Low
<i>Galeocerdo cuvier</i>	Tiger Shark	TA2	11.5	N	0	0	2.57	1.50	2.90	Med
<i>Globicephala macrorhynchus</i>	Shortfinned Pilot Whale	TA2	18.0	N	0	0	2.71	1.50	2.95	Med
<i>Isurus oxyrinchus</i>	Shortfinned Mako or Blue Pointer	TA2	9.2	N	0	0	2.71	1.50	2.95	Med
<i>Negaprion brevirostris</i>	Lemon shark	TA2	29.1	N	0	0	2.57	1.50	2.98	Med
<i>Prionace glauca</i>	Blue Shark	TA2	4.4	N	0	0	2.43	1.50	2.85	Med
<i>Scomberomorus brasiliensis</i>	Serra Spanish mackerel	TA2	32.0	N	0	0	1.57	1.67	2.29	Low



<i>Scomberomorus regalis</i>	Cero mackerel	TA2	9.1	N	0	0	1.57	1.67	2.29	Low
<i>Sphyrna lewini</i>	Scalloped Hammer-head	TA2	23.2	N	0	0	2.71	1.50	3.10	Med*
<i>Sphyrna mokarran</i>	Great Hammer-head	TA2	77.0	N	0	0	2.86	1.50	3.15	Med*
<i>Tursiops truncatus</i>	Bottlenose Dolphin	TA2	44.2	N	0	0	2.86	1.50	3.15	Med*

### 3.5.1 PSA Plot for individual units of analysis (Step 4)

The average productivity and susceptibility scores for each unit of analysis (e.g. for each species) are then used to place the individual units of analysis on 2D plots (Figures 1 & 2). The relative position of the units on the plot indicates relative risk at the unit level. The overall risk value for a unit is the Euclidean distance from the origin of the graph. Units that fall in the upper third of the PSA plot are deemed to be at high risk. Units with a PSA score in the middle are at medium risk, while units in the lower third are at low risk with regard to the productivity and susceptibility attributes. The divisions between these risk categories are based on dividing the area of the PSA plots into equal thirds. All productivity and susceptibility scores (scale 1-3) are assumed to be equally likely, and so 1/3rd of the Euclidean overall risk values will be greater than 3.18 (high risk), 1/3rd will be between 3.18 and 2.64 (medium risk), and 1/3rd will be lower than 2.64 (low risk).

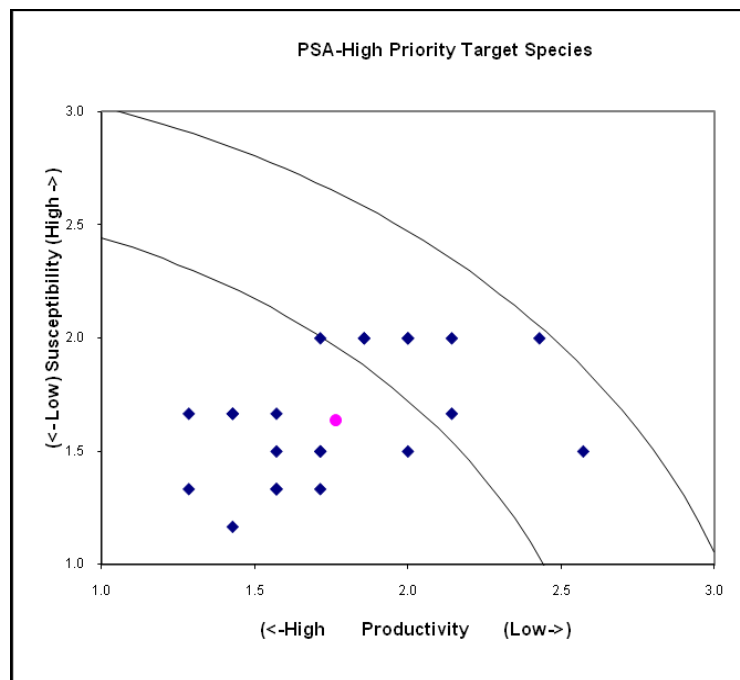


Figure 1: PSA plot for high volume target species (TA1). The magenta dot in the centre of the plot indicates the average risk for this component. Those species at highest risk from fishing activities, in this case, located in the medium vulnerability category, include: Bull Shark, Caribbean Reef Shark, Sailfish, Smoothhound Shark, Cuban Dogfish Shark, Albacore, Swordfish.

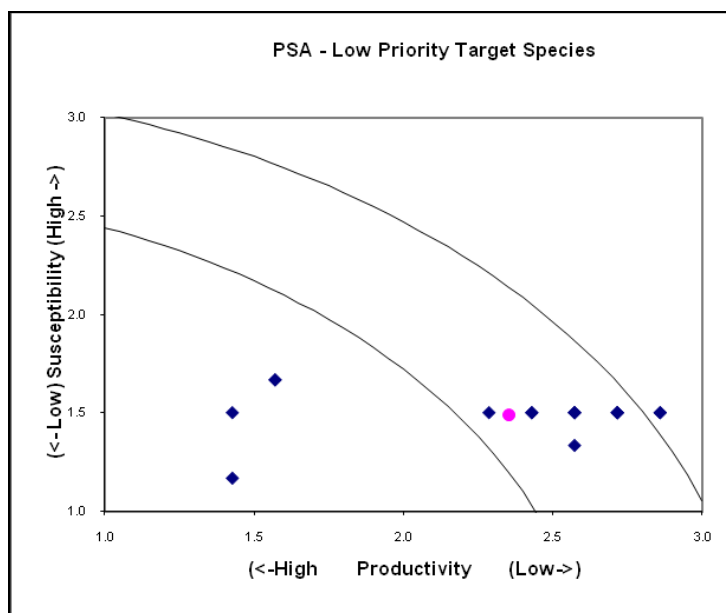


Figure 2: PSA plot for low volume target species (TA2). The magenta dot in the centre of the plot indicates the average risk for this component. Those low-priority target species at highest risk from fishing activities, in this case located in the medium vulnerability category, include: Thresher Shark, Spinner Shark, Silky Shark, Black-tip Shark, Grey Nurse Shark, Tiger Shark, Short-finned Pilot Whale, Short-finned Mako Shark, Lemon Shark, Blue Shark, Scalloped Hammerhead, Great Hammerhead, Bottlenose Dolphin. The latter three species were at highest risk, located close to and within the “High Vulnerability” category with scores of 3.10, 3.15, and 3.15 respectively.

### 3.5.2 Overall Vulnerability

Species were then listed in order of increasing vulnerability according to their respective PSA scores (Table 13).

Table 13: Species listed in ascending order of their PSA overall vulnerability scores.

Scientific Name	Common Name	Role in Fishery	2D vulnerability value	Vulnerability Category
<i>Coryphaena hippurus</i>	Common dolphinfish	TA1	1.84	Low
<i>Coryphaena equiselis</i>	Pompano dolphinfish	TA2	1.84	Low
<i>Sarda sarda</i>	Bonito	TA1	1.85	Low
<i>Caranx lugubris</i>	Black jack	TA2	1.95	Low
<i>Elagatis bipinnulatus</i>	Rainbow runner	TA1	2.06	Low
<i>Euthynnus alleteratus</i>	Little Tunny	TA1	2.06	Low
<i>Thunnus albacares</i>	Yellowfin Tuna	TA1	2.06	Low
<i>Auxis thazard</i>	Frigate mackerel	TA1	2.10	Low
<i>Sphyrnaea barracuda</i>	Great Barracuda	TA1	2.17	Low
<i>Acanthocybium solandri</i>	Wahoo	TA1	2.17	Low
<i>Thunnus atlanticus</i>	Blackfin tuna	TA1	2.20	Low
<i>Tetrapturus albidus</i>	White marlin	TA1	2.28	Low
<i>Thunnus obesus</i>	Bigeye Tuna	TA1	2.28	Low
<i>Katsuwonus pelamis</i>	Skipjack Tuna	TA1	2.29	Low
<i>Scomberomorus brasiliensis</i>	Serra Spanish mackerel	TA1	2.29	Low
<i>Scomberomorus regalis</i>	Cero mackerel	TA2	2.29	Low

<i>Makaira nigricans</i>	Blue marlin	TA1	2.50	Low
<i>Scomberomorus cavalla</i>	King mackerel	TA1	2.63	Low
<i>Mustelus canis</i>	Dusky smoothhound shark	TA1	2.71	Med
<i>Istiophorus albicans</i>	Sailfish	TA1	2.73	Med
<i>Thunnus alalunga</i>	Albacore	TA1	2.73	Med
<i>Carcharhinus limbatus</i>	Black-tip shark	TA2	2.73	Med
<i>Mustelus higmani</i>	Smalleye smoothhound shark	TA1	2.83	Med
<i>Xiphias gladius</i>	Broad Billed Swordfish	TA1	2.83	Med
<i>Carcharhinus falciformis</i>	Silky Shark	TA2	2.85	Med
<i>Carcharhinus brevipinna</i>	Spinner shark	TA2	2.85	Med
<i>Prionace glauca</i>	Blue Shark	TA2	2.85	Med
<i>Carcharias taurus</i>	Grey nurse shark	TA2	2.90	Med
<i>Galeocerdo cuvier</i>	Tiger Shark	TA2	2.90	Med
<i>Carcharhinus perezii</i>	Caribbean Reef Shark	TA1	2.93	Med
<i>Alopias vulpinus</i>	Thintail Thresher Shark, thresher shark	TA2	2.95	Med
<i>Globicephala macrorhynchus</i>	Short-finned Pilot Whale	TA2	2.95	Med
<i>Isurus oxyrinchus</i>	Shortfin Mako	TA2	2.95	Med
<i>Carcharhinus leucas</i>	Bull Shark	TA1	2.98	Med
<i>Negaprion brevirostris</i>	Lemon shark	TA2	2.98	Med
<i>Sphyrna lewini</i>	Scalloped Hammerhead	TA2	3.10	Med
<i>Squalus cubanesis</i>	Cuban Dogfish shark	TA1	3.15	Med
<i>Sphyrna mokarran</i>	Great Hammerhead	TA2	3.15	Med
<i>Tursiops truncatus</i>	Bottlenose Dolphin	TA2	3.15	Med

### 3.5.3 TEP Species

A noted difference between analysis of TEP species and those listed as target is that the latter category is listed as such because they are known to be caught by the fishery, whereas TEP species are included in the analysis if they are known to occur in the area regardless of their interaction with the fishery. These points in mind, it is assumed that there will be more false positives for TEP species generated by the PSA analysis unless there is a comprehensive and robust observer program in place for the fishery that can verify which species do and do not interact with the fishing gear. Observer data and observer expert knowledge are important sources of information in the PSA analyses, particularly for the TEP component. There is no observer program currently in place for this fishery. Hence, the PSA for TEP species was not attempted for the purposes of the present study.

## 4. DISCUSSION

The present study was undertaken to investigate data improvement needs for application of analysis tools that could generate management advice for large pelagic fisheries incorporating ecosystem considerations. The ERAEF method was applied to test such capacity and potential of the present large pelagic fishery data systems in the Eastern Caribbean. Exploration of ERAEF also facilitated consideration of its possibilities generally for application in CRFM fishery situations.

In our study, we faced data and information challenges at every level of analysis within ERAEF, from the initial scoping exercise to the PSA level. In some cases, data and information were available in old paper reports that were few and also stored in such a manner that access was considerably limited. Some national fisheries agencies also had some of their historical fisheries data only in hard copy format, and this prevented easy usage of these data for the present study. Where data were accessible, it was limited

both in quality and quantity. Several data deficiencies were noted: incomplete time series of catch data; uncertainties about sampling coverage throughout the history of the fishery; uncertainties about total catches; catches not reported by individual species; discrepancies between catch data appearing in the various databases consulted such as national fisheries databases, ICCAT and FAO; incomplete documentation about the nature and extent of fishing operations and how these have changed over time; little or no information on the nature and distribution of habitats and on marine community ecology. Of course, some of the habitat and community data and information might be expected to be generated by research studies, but reports of such studies were not readily accessible.

Despite the data challenges, we undertook to test and complete the scoping, drafting of management objectives, hazard identification, SICA, and PSA components of ERAEF. We found that the fisherfolk were reasonably cooperative in sharing their knowledge of fishing operations, which proved valuable not only for completing the scoping analysis but also for informing the drafting of management objectives and the identification of hazardous activities.

A number of hazardous activities associated with fishing were identified, as well as hazards caused by non-fishing activities such as seismic surveys conducted by the petroleum industry and general large-scale shipping activities. In respect of fishing, the associated risks rated as moderate/major (consequence scores of 3 or above) were all related to direct or indirect impacts from primary fishing operations. Fishing (with or without direct capture) by both the Eastern Caribbean large pelagic fishing fleet and other fisheries targeting similar species were expected to have at least moderate impacts on the sizes of target species populations, and were therefore scored as such. Also, fishing with FADs was believed to impact species behaviour and movement. On-board fish processing was noted to be associated with at-sea discards of biological remains that attracted sharks, and so had the potential to impact the behaviour and movement of both target and TEP shark species. Garbage disposal by fishers during fishing trips was estimated to pose a moderate potential risk to turtles which were known to ingest food packaging material. In the case of the seismic surveys and shipping, each of these had at least moderate potential to affect species behaviour and movement.

Using landings data and a lower cumulative catch limit of 100 tons over the period 2000-2011 to identify high priority target species, our results indicated that as many as 23 species were being harvested regularly by the large pelagic fishery in the eastern Caribbean. An additional 16 species were also being caught by large pelagic fishing gears, but due to the small landings (< 100 tons total during 2000-2011) these were treated as low-priority target species in our analysis. Based on guidance provided by Hobday *et al.* (2007) and IUCN species status lists, a total of 65 species were identified as Threatened, Endangered or Protected (TEP) species, due to their occurrence in the study area; this list included 23 marine mammal species, 22 marine bird species, 15 species of cartilaginous fish species (sharks and sawfishes), and 5 marine turtle species.

In the eastern Caribbean large pelagic fishery, the most important target species were: Spanish mackerel, mostly taken in the southern part of the study area in the region of Trinidad and Tobago, yellowfin tuna, the common dolphinfish, king mackerel, blackfin tuna, wahoo and skipjack tuna. These species were all estimated to have low overall vulnerability for the effects of fishing, as the PSA vulnerability scores were in the lower third of possible scores (<2.64). Hence, the status of the fishery and its impacts would appear to be stable for the major target species based on this initial evaluation. However, of a total of 39 target species (23 high priority and 16 low priority species) considered, the PSA analysis showed 18 species to be at low risk and 21 species to be at medium risk. Of the 18 low-risk species, 15 were high priority target species. Hence, many more low priority target species (13 out of 16) were at medium risk from fishery operations. In view of this, management of this fishery could contribute significantly to ecosystem health by considering options to reduce fishery impacts on the low priority target species, and arguably with minimal impact on human social and economic well-being.

However, certain species that were estimated to be at low risk by the PSA with regard to fishing operations in the study area, included species such as blue and white marlin for which traditional quantitative stock assessments have indicated both an overfished and overfishing situation (ICCAT 2012). The ICCAT assessments would be equivalent to the final analysis level of ERAEF that would be quantitative, and hence arguably, would provide the most reliable result. While the ICCAT assessments were known to suffer from data deficiencies, the PSA scores of the present study used various measures of productivity and susceptibility that were borrowed from other data sources. As such, the present PSA scores would be preliminary, being generated as a result of exploration of the ERAEF method. Future ERAEF application efforts for this fishery would therefore need to improve the PSA attribute measurements to the extent possible.

As we expected, the ERAEF method provided a very logical, progressive approach to examining fishery situations and their impacts, both at the individual unit level, in our case target species, and at the overall ecosystem level that took into account a broad range of possible fishery/ecosystem/other activity interactions that were categorized for easier focus of attention. Though the method allows several biotic and abiotic components of the ecosystem to be analysed simultaneously, we were not able to examine the method for all the ecosystem components, particularly the components dealing with habitats and communities, due to difficulties in accessing the limited data available and also due to the time constraints of the study.

In conclusion, these results, though preliminary, identified certain hazards with at least moderate associated risks, and also indicated levels of overall vulnerability for the various target species identified. However, capacity to make full use of ERAEF and its application potential would require that countries invest resources in a broader level of monitoring than is currently the case for many CRFM fisheries.

Although direct capture by fishing (catches and fishing effort) is already monitored by the countries concerned, there is room for improvement and expansion to facilitate better evaluation of species population sizes, e.g. improvement and consistency in sampling coverage by species, closer monitoring of fishing effort to determine changes in fishing efficiency, catch size composition trends. In addition, ERAEF requires a level of understanding of the biology and ecology of other living communities not taken directly by the fishing gear, and the nature and state of habitats comprising the ecosystem. It is possible that these additional data needs are best addressed through scientific research studies, updated at reasonable time intervals. Ad hoc studies could provide for collection of more detailed data and information, while some basic level of routine scientific monitoring could be undertaken by research institutes working in partnership with national and regional fishing agencies. Countries should also consider options for improving data and information on the hazards caused by external activities, and this could involve partnerships with the petroleum, shipping and tourist industries.

As the name implies, ERAEF focuses primarily on ecological and hence ecosystem-level aspects, and so does not make direct use of social and economic data and information. In this regard, even if ERAEF is applied, the management advice generated would still have to be weighed against the social and economic performance and related goals. In this regard, decision support tools, such as the multi-criteria analysis explored by Ferrier and Singh-Renton (2012) and Campbell and Singh-Renton (2012), would be needed to complement ERAEF outputs for producing advice that could then incorporate the full range of management concerns.

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