

# **Fisheries Management Assessment (FMA Tool)**

## **Guidance**

### **FMA Overview**

#### **Purpose Statement**

This guidance provides information on how to use the FMA tool to assess small-scale fisheries and develop a plan to achieve fisheries goals by adaptive management. The guidance will help you determine the adequate fisheries management measures based on the best available data, assess how management interventions are performing, adjust measures as necessary, and develop an adaptive fisheries management plan.

#### **Suggested Audience**

This guidance is designed as a facilitation document to guide a multi-stakeholder group to reach consensus and make management decisions about a fishery.

#### **Skills Necessary**

The FMA tool requires general knowledge in fisheries ecology, fisheries management, population dynamics of target species, as well as local and regional fishery management regulations. Familiarity working with fisheries data is desired but not required. Facilitation and communication skills are needed to coordinate and lead multi-stakeholder discussions.

#### **Tool Objectives**

The FMA tool framework provides a step-by-step process to assess the performance of data-poor small-scale fisheries, identify appropriate management controls based on the best available information, and adjust management to achieve desirable management objectives. The tool guides managers in:

- Assessing and visualizing available fisheries data.
- Determine what fisheries performance indicators should be used to monitor and evaluate target species overtime.
- Perform data-limited assessment methods to evaluate fisheries performance.
- Determine fisheries management regulations and harvest control rules to achieve fisheries goals (i.e., increasing landings, increase size, etc.)
- Complete a fisheries management plan that defines a process to review management and adapt periodically over time using the best available data and local knowledge

## **When to Use the Tool**

The FMA tool should be used on an annual basis (at least for the first few years of data collection) to use as an adaptive management tool. As time progresses and more data and information become available for the fishery, different performance indicators may be included and more advanced assessment methods may be appropriate. Due to changing biological, ecological, environmental, and socioeconomic conditions, it is also important to perform each assessment method on an annual basis to measure changes in the fishery and adjust fisheries management controls accordingly.

## **Data necessary to use the FMA tool and develop a management plan**

The FMA tool needs a minimum amount of data to be used and develop a fisheries management plan. The primary data in this FMA tool come from catch reporting by buyers using the [OurFish App](#) and from fishery-independent surveys (e.g., underwater visual surveys). Other catch data such as those collected in paper from landing sites, fishery-dependent length composition surveys, and other fishery-independent surveys can be added to the tool using form templates. Below is the minimum data requirements and additional recommended data to conduct a basic fisheries assessment and complete a management plan.

### **Minimum required data** (Local knowledge data)

- Qualitative characterization of the fishery (e.g., local history, gear types, target species, fishing locations, fishing seasons, etc.)
- Existing management regulations or controls.
- Managed access and reserve location (if applicable)
- Information on compliance with managed access and reserve regulations
- List or prioritized target species and goals for management
- Estimated vulnerability of prioritized target species

### **Additional recommended data** (catch data, underwater surveys, household surveys)

- Landings (weight and count), fishing effort (number of trips and fishers reporting)
- CPUE (key target species)
- Length composition data (key target species)
- Fished/Unfished density ratio (key target species)
- Coral reef thresholds (aggregated across species – only for underwater visual survey)
- Household survey data on the community's knowledge, attitudes, interpersonal communication, and practices relating to fisheries management
- Household survey data on the impact fisheries management is having on the community
- Qualitative information on the community's preparedness for implementing fisheries management and what barriers that may need to first be removed

## Supporting Documents

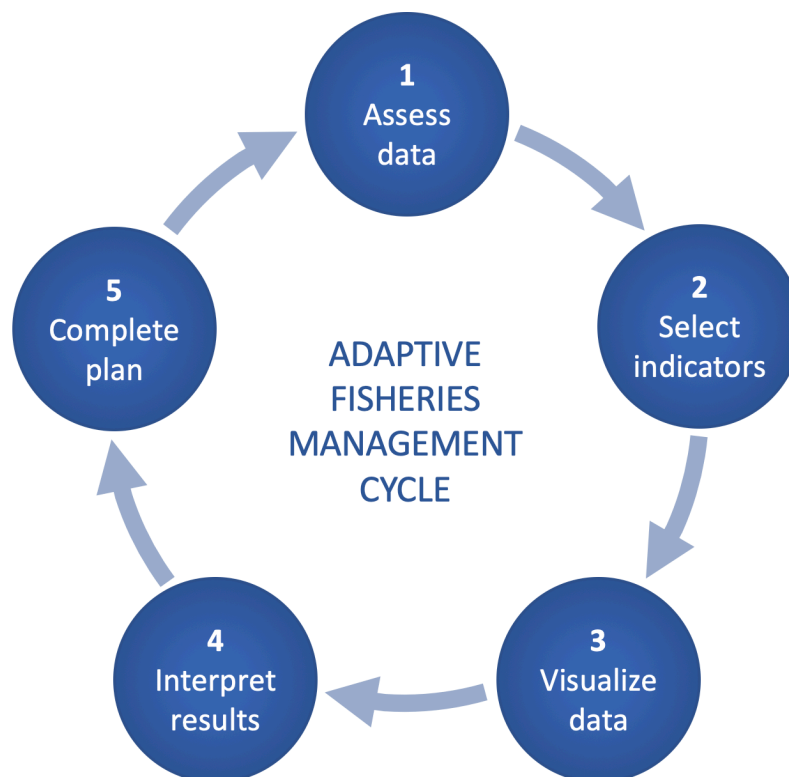
The FMA tool provides practitioners with a streamlined way of assessing data-poor fisheries using the OurFish data and underwater visual surveys (UVC). There are several supporting documents in this guidance that explain in detail fisheries-related concepts such as performance indicators, reference points, management controls, harvest control rules, and results interpretation.

## Previous version of the FMA tool

This tool builds on extensive research in data-limited fisheries assessment and management approaches. Importantly, this tool is based on the Adaptive Fisheries Assessment and Management (AFAM) toolkit developed by McDonald et al., (2017), but specifically adapted to be used with OurFish and UVC data. The former AFAM toolkit used an extensive first-hand experience in designing a similar adaptive management framework for the Belizean conch and lobster fisheries, an initiative undertaken between the Belize Fisheries Department, and several members of the Fish Forever team ([McDonald et al., 2017](#), [Harford et al., 2016](#)).

## Fisheries Management Assessment Framework

The FMA tool will guide you through a comprehensive **five-step** process that should be conducted on an annual basis in performing the data-limited assessments (Fig. 1).



**Figure 1.** Steps for the Fishery Management Assessment (FMA)

## **Step 1 – Assess Data, Select Geography and Target Species**

The data assessment is based on the data available after selecting the geography and target species(s) and will determine, the performance indicator, the assessment methods and, the management options you have at your disposal.

## **Step 2 – Select Performance Indicators, Reference Points**

Performance indicators are numerical values based on available data that provide an indication of how the fishery is performing relative to a reference point. Reference points are either a target where you want the fishery to move towards or a limit where you want the fishery to stay away from. Currently reference points are set for the user based on the data available

## **Step 3 – Visualize Data and Perform Assessment Methods**

The assessment method is the technique for calculating the performance indicators using the available data. For example, a performance indicator could be fishing mortality with a target reference point of natural mortality. In this case, the assessment method to calculate fishing mortality could be a catch curve. Currently assessment methods are already chosen for the user to visualize how selected performance indicators compare to reference points.

## **Step 4 - Interpret Assessment Results and Determine Management Regulations**

Interpret the assessment results for each performance indicator together with local ecological knowledge to determine appropriate fisheries management regulations (management controls and associated harvest control rules). In this tool, we provide possible interpretations that are linked to suggested management regulations.

Fishery management controls allow managers to limit aspects of fishing behavior, reduce fishing mortality, or protect key biological or ecological function (e.g., seasonal closures to protect spawning aggregations). These management controls are evaluated and/or determined after assessment of the available data.

Harvest control rules are specific plans for management actions. Harvest control rules help stakeholders to compare performance indicators with reference points and adjust fisheries management controls accordingly. You will use the harvest control rules and the interpretation of assessment results to adjust fisheries management controls appropriately.

## **Step 5 – Complete Adaptive Fishery Management Plan**

Use the outputs of the FMA tool to fill out a Fishery Management Plan template for a fishery. The template can be adapted to specific fisheries and regions. The completions of the adaptive fisheries management plan require participation local stakeholders.

# FMA Tool Dashboard

## Step 1 – Assess Data, Select Geography and Target Species

Depending on the available data and the time and frequency the data have been collected, each site may have three major type of assessment and management categories with a minimum amount of data required (Table 1). Being clear in the assessment and management categories is crucial to adequately assess your fishery.

### Dashboard Steps:

**Step 1a** – Select the data source by choosing the already loaded OurFish Data, or upload new data using the template provided

The FMA tool already comes pre-loaded with the most current data that is being collected from the OurFish App, generally within a week of data collection.

The FMA tool includes data templates you may fill out using your own data to ensure all data are properly formatted for analysis. A excel template can be downloaded and filled out to upload new fisheries data such as landings and length composition data that is not being collected through the OurFish app. The template follows the same format as the OurFish data. Make sure your data has all necessary column names. Note, all column names **must match exactly** what is specified in the dashboard. If specific data is not available (e.g., counts) leave columns blank.

**Step 1b** – Select the geography of interest by choosing country, subnational government, local government, and managed access area

You can select more than one geography level at the time for analysis (e.g., more than one local government). Calculations will be aggregated at the highest level selected. That is, if for example, three managed access are selected, total landings will be aggregated across the three geographies. Currently, however, only one country at the time should be selected as they usually have different target species and management regulations.

**Step 1c** – Select the target families or species of interest

Select one, several or all target families of interest. For each family select one, several of all species. You can also select specific species within each family. Note that families and species will vary depending of the geography selected.

**Step 1d** – Select the time frame you would like to analyze

Currently, available data starts on January of 2019. However, reporting effort increased in the first six months of data collection so it is recommendable to start any analysis of fisheries performance after June 2019. Note that reporting effort in every country is variable and the user should assess when is the more reliable starting date for analysis.

## Step 1e – Determine assessment and management category

Determine what assessment and management category is the most appropriate based on the availability and amount of data (see Table 1). As you collect more data over time, you may be able to move from one category to the next to assess your fishery.

**Table 1.** FMA tool assessment and management category with amount of data required

Assessment and Management category	Amount of data required
<b>Precautionary</b> assessment and management	New sites with < 1 year catch/effort data, length-composition data, and underwater visual survey data
<b>Preliminary</b> adaptive assessment and management	About 1 year of catch/effort data and length-composition data
<b>Multi-indicator framework</b> for adaptive assessment and management	One or more years of catch/effort data and length-composition data

Sites with these three assessment and management categories are described below.

### *Precautionary Assessment and Management (<1 year of data)*

This is generally a new site with no pre-existing standardized data collection. Qualitative information and local ecological knowledge may be available. With this limited amount of data, managers can perform a basic fisheries assessment and select precautionary fisheries management controls until more data is collected. For example, limiting the use of destructive fishing gears and/or practices, and protecting spawning aggregations through seasonal closures are effective precautionary management techniques.

### *Preliminary Adaptive Assessment and Management (~1 year of data)*

This describes a site with roughly one year of OurFish data, or a combination of paper reporting, boat intercept or landing surveys, or fishery-dependent length-composition surveys. This category provides a preliminary assessment and management methods for a fishery. Several fisheries management controls can be used in combination to meet multiple management objectives.

### *Multi-Indicator framework for Adaptive Assessment and Management (>1 year of data)*

This site may have over a year of time-series data that can be used to determine temporal trends in multiple performance indicators and develop a more informed assessment and fisheries plan. Here, target species may be assessed by multiple performance indicators based on different data streams (e.g., total landings, catch per unit of effort, length-composition). Multiple performance indicators provide a more complete understanding of the fishery and reduce uncertainty associated with any single

indicator or data stream. Corroboration between multiple indicators can also allow for a confident interpretation of fishery performance. Overtime, with time series data, limits and targets reference points can be estimated from running averages or the average of the past few years that account for variability in the environment and the fishery.

## **Step 2 – Select Performance Indicators, Reference Points, and Assessment Methods**

Performance indicators and reference points should be based on the community goals for your fishery. For example, if increased landings for food provision is a goal, landings may be used as a performance indicator and increasing trends in landings as a reference point. If conservation of fish biomass within reserves is a goal, fished/unfished density ratio may be use as performance indicator and a relatively high fished/unfished density ratio as the target reference point. If there are several fishery goals, a combination of performance indicators may be necessary.

### **Step 2a – Select performance indicators**

Select appropriate performance indicators for your fishery using **Table 2.1** as guidance. Assess the pros, cons, and the types of species each indicator is appropriate for. Selected performance indicators will depend on minimum data requirements that will inform the category of assessment and management (see Table 1). Whenever possible, chose multiple indicators from multiple independent data streams to reduce the uncertainty associated with any single data stream and to provide a complete picture of the fishery. We generally recommend using 3 performance indicators from 3 independent data sources if possible. Use the specific guidance below for the assessment category selected.

#### ***Precautionary Assessment and Management (new sites < 1 year of data)***

With less than one year of data, managers can perform a basic qualitative fisheries assessment using local ecological knowledge about the fishery, such as types of fishing gear used, changes in reporting effort and/or fishing season, and changes in species composition of landings over time (**Table 2.1**).

For a precautionary assessment, at a minimum, we recommended using these performance indicators:

- At least one indicator based on qualitative fisheries characterization
- At least one fishery-independent indicator based on underwater visual survey

#### ***Preliminary Adaptive Assessment and Management (~ 1 year of data)***

Performance indicators in a preliminary adaptive assessment included those under the precautionary assessment, as well as at least one year of fishery-dependent data such a combination of catch reporting, boat-intercept surveys, and length-composition surveys (**Table 2.1**).

For a preliminary assessment, at a minimum, we recommended using these performance indicators:

- All indicators from the precautionary assessment
- At least one indicator based on fishery-dependent data (e.g., length-composition)

***Multi-Indicator framework for Adaptive Assessment and Management (>1 year of data)***

These sites/fisheries will have time series data to examine trends in multiple performance indicators in addition to information and data described under the precautionary and preliminary assessment (**Table 2.1**).

For a multi-indicator assessment, at a minimum, we recommended using these performance indicators:

- All indicators from the precautionary and preliminary assessment
- At least one trend-based indicator that uses a time series (landings or CPUE data)

**Table 2.1** Pros and cons of performance indicators. Performance indicators marked with an asterisk (\*) are not currently included in the FMA tool.

Assessment Category	Performance Indicator	Pros	Cons
Precautionary	<b>FISHING GEAR</b>	Relatively easy metric to monitor using local ecological knowledge.	None
Precautionary	<b>REPORTING EFFORT</b>	Relatively easy metric to monitor using local ecological knowledge and/or OurFish data.	Changes in reporting effort do not always indicate change in fishing season; this may also result from changing environmental or market conditions, or lack of adequate reporting.
Precautionary	<b>SPECIES COMPOSITION</b>	Relatively easy metric to monitor using local ecological knowledge and/or OurFish data.	Changes in target species composition do not always indicate poor fisheries performance; this may also result from changing environmental, market conditions, or reporting effort.
Precautionary	<b>SPECIES VULNERABILITY*</b>	Easy to interpret a species' relative vulnerability to overfishing relative to other species in the area/ecosystem. This	It is not an estimate of stock status.

		relative vulnerability score can be used to prioritize species for management.	
Precautionary	<b>FISHED: UNFISHED DENSITY RATIO*</b> (for key target species)	A relative quick way to assess the status of target species based on underwater visual surveys	Assumes that a fully-functioning and well-enforced marine reserve has been appropriately sited with representative habitat. Not useful for highly mobile targets.
Precautionary	<b>FISHED: UNFISHED BIOMASS RATIO*</b> (coral reef threshold aggregated across species)	Provides an estimate of ecosystem status and capacity to support fishing, useful for setting precautionary management to meet ecosystem-based fisheries management goals.	Assumes that a fully-functioning and well-enforced marine reserve has been appropriately sited with representative habitat. Not useful for highly mobile targets. Assumes marine reserves are representative of historical, unfished biomass.
Preliminary	<b>AVERAGE LENGTH *</b> (from UVC)	Easy metric to assess	It does not capture selectivity of the fishery, or if fishing is occurring in nursery grounds.
Preliminary	<b>FISHING MORTALITY*</b>	Mortality rates are critical for estimating abundance of fish populations	Difficult to estimate. Assumes equilibrium conditions. Mostly reflect fish that have recruited to a fishery and does not reflect the full age structure of a stock.
Preliminary	<b>SPAWNING POTENTIAL RATIO (SPR) *</b>	It can be used with fishery independent and dependent data	Assumes equilibrium conditions. It is an index based on the early life history of a fish. It does not consider what happens to the fish before they are large enough to harvest.
Preliminary	<b>AVERAGE LENGTH</b> (from catch)	Easy metric to assess changes in the status of a fishery when stratified across sampling unit (gear, efforts, fishing zone)	Historical information on the length of the catch and/or information on gear selectivity are needed to prevent bias in the

			interpretation of size distributions.
Preliminary	<b>FROESE INDICATORS</b>	Proved estimate of the status of the stock, in comparison to sustainability reference points	It does not contribute to biomass sustainability reference points.
Multi-Indicator	<b>CPUE</b>	It can be used to infer population trends of an exploited stock. Standardized time series of CPUE are often regarded as indices of abundance.	Seldom proportional to historical abundance of an entire geographic range. Can be skewed, depending on sampling regime and reporting effort. May have species-specific biases.
Multi-Indicator	<b>TOTAL LANDINGS</b>	When sampling is stratified, can provide an estimate of abundance	Seldom proportional to historical abundance of an entire geographic range, because of fishing location biases and lack of sampling stratification.

## Step 2b – Familiarize with reference points

Currently, reference points for each performance indicator are set for the user. However, as more data is available, the user will have the option to select specific reference points for some performance indicators (e.g., average total landings, CPUE). **Table 2.2** offers guidance on selection of generic reference points for each performance indicator. This information come from the literature or historic data. You should consult scientists for advice for appropriate reference points is needed.

For each performance indicator, a **target reference point** (TRP) and a **limit reference point** (LRP) is selected. TRP is a numerical value (chosen from the literature) or a trend (compare to historical data) that indicates a desirable level of performance for the fishery. **A fishery moving toward a TPR is considered low risk.** Management is often aimed to achieve or maintain this target. LRP is a numerical value that indicates that the fishery's performance is unacceptable (e.g., overfished). **At or below LRP the fishery is considered at high risk,** and management action is required to improve it or restore populations.

**Table 2.2.** Selecting performance indicators and reference points. Performance indicators marked with an asterisk (\*) are not currently included in the FMA tool.

Data Stream	Performance Indicator	Target Reference Point (low Risk)	Limit Reference Point (high risk)
Qualitative survey and/or OurFish Data	<b>FISHING GEAR</b>	No destructive fishing practices being used	Destructive fishing practices being used
	<b>REPORTING EFFORT</b>	No changes in the reporting effort	Increased variability in reporting effort, or decreased reporting effort
	<b>SPECIES COMPOSITION</b>	No changes in the composition of caught species	Changes in the composition of caught species (e.g., fewer species) or loss of major fishing targets, predators and grazers.
Productivity and Susceptibility Analysis (PSA)	<b>SPECIES VULNERABILITY *</b>	Low vulnerability estimate (< 2.0 PSA score). Low-medium susceptibility and high-medium productivity species are a lower priority for management action relative to species with higher vulnerability estimates (>2.0 PSA score)	High vulnerability estimate (> 2.0 PSA score). High susceptibility and medium or low productivity species should be high priority for management action and frequent assessment
Underwater visual surveys	<b>FISHED/UNFISHED DENSITY RATIO *</b> (for key target species)	Fished/unfished density ratio > 0.6	Fished/unfished density ratio < 0.4
	<b>FISHED/UNFISHED BIOMASS RATIO *</b> (coral reef threshold aggregate across species)	Fished/unfished biomass ratio $\geq 0.5$	Fished/unfished biomass ratio $\leq 0.25$

Data Stream	Performance Indicator	Target Reference Point (low Risk)	Limit Reference Point (high risk)
	<b>AVERAGE LENGTH*</b> (from UVC data)	Decrease in the size of unfished individuals outside of the marine reserve, in comparison to previous years	Rapid decrease in the size of individuals outside of the marine reserve, in comparison to previous years
OurFish Data  and/or  Fishery dependent length-composition survey  (For OurFish data, average length is estimated from weight-length allometric relationships)	<b>FISHING MORTALITY/ NATURAL MORTALITY RATIO (F/M) *</b>	$F/M < 1$ (F is fishing mortality, M is natural mortality)	$F = 2M$
	<b>SPAWNING POTENTIAL RATIO (SPR) *</b>	Slow growing species, $M/k < 1$ (fish) $SPR \geq 40\%$  Fast growing species, $M/k > 1$ (invertebrate) $SPR < 20\%$  <i>M is natural mortality, k is von Bertalanffy growth rate)</i>	Slow growing species, $M/k < 1$ (fish) $SPR < 40\%$  Fast growing species, $M/k > 1$ (invertebrate) $SPR < 20\%$
	<b>AVERAGE LENGTH</b> (from catch data)	Increase in average length of mature adults	Decrease in average length of mature adults
	<b>FROESE INDICATORS</b>	> 90% of the catch are mature adults  > 80% of catch – optimal  < 20% of the catch are <i>mega-spawners</i>	< 50% of the catch are mature adults  < 50% of catch – optimal  > 40% of the catch are <i>mega-spawners</i>
OurFish Data  And/or  Catch reporting system & boat intercept/landing site survey	<b>CPUE</b>	Increasing or Stable	Rapidly decreasing CPUE, in comparison to previous year or to running average
	<b>TOTAL LANDINGS</b>	Increase or Stable	Rapidly decreasing total landings, in comparison to previous year or to running average

## Step 3 – Visualize Data and Perform Assessment Methods

### Step 3a – Visualize the data

Data visualization for each performance indicator happens automatically based on the most appropriate assessment method and data available. Note that a warning message will appear if there is not enough data to calculate a selected performance indicator with the current selections of geographies, families, species, and time frame. We recommend to familiarize with each assessment method (**Table 3.1**) and the minimum data requirements (Table 1, and 2.1) to adequately interpret the results you see in the graphs.

For each performance indicator the user will be able to:

- Adjust date range as desired.
- Change the smoothing of the LOESS (locally estimated scatterplot smoothing) curve for those performance indicators that vary over time. A loess curve can serve as exploratory method to see trends in subsets of the data. Numbers close to 1 produce smoother curves and numbers close to 0 produce wiggler curves.
- Select the time brake interval to aggregate the calculations for each performance indicator (e.g., month, week, day)

### Step 3b – Familiarize with the assessment methods

Currently, the appropriate assessment method for each performance indicator is already used in the tool and the indicators are automatically calculated. Most performance indicators are calculated using one assessment method, but each indicator may be appropriate for different target species (e.g., multi-specific, species-specific, only fish, fish and invertebrates) (see **Table 3.1**). For detailed description, inputs, outputs, management use, sensitivity, and caveats of each assessment method see **Appendix 1**.

### Step 3c – Assess the performance indicator against the reference points.

During data visualization, the user will be able to assess how the selected indicator is performing against reference points. Results in green indicate significantly good performance against reference points, results in red indicate significantly bad performance against reference points, and results in grey indicate no significant change.

The FMA toll dashboard currently comes pre-loaded with the necessary life history information for many reef fish and invertebrate species commonly found in the Brazil, Honduras, Mozambique, Indonesia, and the Philippines.

**Table 3.1.** Performance indicators, associated assessment method and appropriate target species. Performance indicators marked with an asterisk (\*) are not currently included in the FMA tool.

Performance Indicator	Assessment Methods	Target Species
<b>FISHING GEAR</b>	Qualitative assessment of MA-Reserve	All fish and invertebrates
<b>REPORTING EFFORT</b>	Trends in reporting effort from OurFish data	All fish and invertebrates
<b>SPECIES COMPOSITION</b>	Qualitative assessment of MA-Reserve Trends in reporting effort from OurFish data	All fish and invertebrates
<b>SPECIES VULNERABILITY *</b>	Productivity and susceptibility analysis	All fish and invertebrates
<b>FISHED/UNFISHED DENSITY RATIO *</b> (for key target species)	Density ratio	Fish and invertebrates that are habitat associated (not a good indicator for highly mobile species)
<b>FISHED/UNFISHED BIOMASS RATIO *</b> (coral reef threshold aggregate across species)	Coral reef thresholds	Multi-species finfish fisheries
<b>AVERAGE LENGTH*</b> (from UVC data)	Average length	Multi-species, habitat associated targets (not a good indicator for highly mobile species)
<b>FISHING MORTALITY/ NATURAL MORTALITY RATIO (F/M) *</b>	Catch curves Mean length assessment (LBAR)	Finfishes (groupers), and invertebrates with indeterminate growth (lobster, crabs). Use with care for targets that have deterministic growth and episodic recruitment.

Performance Indicator	Assessment Methods	Target Species
<b>SPAWNING POTENTIAL RATIO (SPR) *</b>	Length-based SPR (LBSPR)	Finfishes (groupers), and invertebrates with indeterminate growth (lobster, crabs). Use with care for targets that have deterministic growth and episodic recruitment.
<b>AVERAGE LENGTH</b> (from catch data)	Average length	All targets, especially nearshore species. In an ideal scenario an historic record of average length would be used to compare current to past estimates.
<b>FROESE INDICATORS</b>	Froese sustainability indicators	All fish and invertebrate target with known length-age/maturity relationships. Species-specific.
<b>CPUE</b>	Catch trends	All targets that do not have high selectivity of habitat stratification.
<b>TOTAL LANDINGS</b>	Catch trends	All targets that do not have high selectivity of habitat stratification.

## Step 4 - Interpret Assessment Results and Determine Management Regulations

### Step 4a – Assess possible interpretations for each performance indicator

After the data visualization and assessment methods are completed, determine the possible interpretation and management implication for each performance indicator following these steps:

- Using your assessment results, select the most likely interpretation from the choices provided in the “Possible Interpretation” column (**Table 4.1**). The list of possible interpretations is not exhaustive; thus, the user should use this as a guide. Think about other possible interpretations that are not in this table and may better explain the assessment results.
- Determine the management implication by locating the colored circle traffic light in the “Risk Level” column.

Each row also has a traffic light indicator that describes the management response level:

- Green (●) indicates that either no management response is necessary, or management could be less restrictive.
- Yellow (●) indicates that a precautionary or more restrictive management response should be implemented.
- Red (●) indicates that the fishery should be closed and a fishery recovery plan implemented.

Because of the different data streams, assessment methods, and fishery component represented by each performance indicator, it is possible that assessment results will reveal some performance indicators falling above their targets, while others fall below them.

### **Step 4b – Verify and interpret assessment results**

Verify the assessment result using the following steps:

1. Double-check that each assessment performed was stratified to the spatial extent of the target fishery; for example, run analyses for the target managed access area(s).
2. Double-check that each assessment performed is adequate for the available data (e.g., to interpret CPUE and total landings you need more than 1 year of data)
3. Double-check that reference points are appropriate for your fishery using available literature, expert opinion, and local ecological knowledge.
4. Assess whether trends and results of performance indicators are actually driven by reporting effort.
5. Importantly, ground-truth assessment result and interpretation with community members. Consult with local experts (i.e., fishers, buyers, village elders, scientists, etc.) to determine if the assessment results align with their knowledge of the fishery. Often, assessment results can be counterintuitive, and multiple performance indicators may be conflicting in their message and can be explained by fisher's behavior (e.g., if fished/unfished density ratio is down but total landings and CPUE are up this could be associated with higher prices and good weather during the season).
6. If each performance indicator points towards a consistent interpretation and if the community agrees with the interpretation, proceed to adjust fisheries management controls using defined harvest control rules (**Step 4c**)
7. In situations where, conflicting indicators cannot be rectified, or if the community cannot corroborate the assessment results, additional community outreach may be necessary to arrive at consensus. It is important that all stakeholders are comfortable and confident with the assessment interpretation because it will be used to trigger a harvest control rule in **Step 4c**.

## **Step 4c – Defined Harvest Control Rules**

After interpreting and verifying the assessment results, define the appropriate Harvest Control Rules (HCRs) triggered by the interpretation(s) selected (use **Table 4.1** as framework). This table contains the performance indicators that are associated with each assessment category and suggests HCRs from the literature and relevant to managed access areas. It is important that you define an HCR for every foreseeable interpretation so that management responses can be transparent and objective when the time comes to implement them.

Depending on the severity of the HCR and likely community reaction, it may be necessary to conduct additional community outreach to ensure buy-in and compliance. For example, if a limit reference point is reached and the fishery for a particular species must be temporarily closed, this will likely require significant community outreach. Therefore, HCRs should be based on realistic compliance and enforcement concerns and address community goals for your fishery.

## **Step 4d Adjust Fisheries Management Controls with defined Harvest Control Rules**

HCRs will be used to adjust Fisheries Management Controls (FMC) according to where the fishery's performance indicators fall relative to their reference points. The HCR may specify some combination of adjustments to the FMCs that is expected to move the performance indicator towards the target reference point, and away from the limit reference point, therefore improving the performance of the fishery.

It is important for stakeholders and managers to agree on the suite of HCRs in a safe and neutral setting before any management decisions need to be made. This can help improve compliance by ensuring management responses are objective, consistent, transparent, and appropriate. Therefore, it is important to identify all foreseeable possible scenarios that could occur in the fishery and create corresponding HCRs for each scenario.

## **Step 4e – Add specificity to harvest control rules with community participation**

With community participation, add specificity to your HCRs (e.g., if the CPUE indicator is 20% below the target reference point, reduce fishing effort by 20% by limiting the number of fishing licenses or access to the fishing area).

Be as specific as possible when defining the magnitude to which FMCs should be adjusted given the fishery's performance indicator.

The magnitude that an HCR should adjust your FMC(s) will depend on:

1. Productivity (life history) of the target species
  - a. Find the level of productivity of key target species.
  - b. Species with low productivity will require higher, more restrictive levels of response when changes are necessary; species with higher productivity will require lower levels of response when changes are necessary.
2. Likelihood of compliance with regulations

3. Social and political feasibility
4. Enforcement capacity
5. Level of uncertainty with data and the estimation of performance indicators
  - a. The more uncertain you are about the performance of indicators, the more precautionary you may want to make your management
6. **Risk** tolerance
  - a. Communities with higher risk tolerance may choose to be more lenient when choosing HCRs, while communities with lower risk tolerance may choose more restrictive HCRs to be more precautionary in the face of changing and uncertain conditions.






Consult any existing household survey or KAP data when setting HCRs. These data will provide an indication as to individual attitudes towards fishery management in your community. Social survey data will provide context as to how dependent the community is on the fishery and how changes in fisheries management controls may affect their livelihoods. Additionally, any existing enforcement data should be consulted to gain a better sense for the likelihood of compliance with any new regulations.

Consider also the size of existed marine reserves when setting HCRs. Sites with small marine reserves relative to the size of the fishery may wish to set more restrictive HCRs. Sites with a marine reserve that is not placed explicitly in areas that protect critical habitat may also wish to set stricter HCRs. Sites with larger marine reserve that protect a significant portion of critical habitat could be more lenient in their HCRs. Often, large and well-placed marine reserves can act as a buffer against uncertainty and variability.






By completely restricting access to a certain portion of the stock, marine reserves are analogous to an emergency savings account. Protecting a fraction of a fish stock in reserves reduces the risk of overfishing and the chance of stock collapse in the long term. Displaced fishing effort and unintended consequences resulting after implementation of a reserve can be mitigated when effective FMCs are in place outside of the reserve. When harvest levels are appropriately controlled a spillover of biomass from marine reserves to the adjacent fishery may occur that can benefit fisheries.


**Table 4.1.** Performance indicator, assessment result, possible interpretations, management response, and suggested harvest control rules. The stoplight indicator describes the level of management response necessary where green circles indicate that that either no management response is necessary, or management could be even less restrictive. Yellow circles indicate that a precautionary or more restrictive management response should be implemented. Red circles indicate that the fishery should be closed and a fishery recovery plan implemented.

Performance Indicator	Assessment Result	Possible Interpretation	Risk Level	Management Response	Harvest Control Rule Suggested
<b>Fishing Gear</b>	No destructive fishing practices being used	Non-destructive fishing practices are able to efficiently catch fish and/or destructive fishing practices have been banned	Low	●	1. Make no changes to fishing practices
	Destructive fishing practices being used	Non-destructive fishing practices are no longer able to efficiently catch fish and/or destructive fishing practices have not yet been banned	High	●	1. Ban destructive fishing practices
<b>Reporting Effort</b>	No change	Number of fishers and/or buyers reporting catch has not significantly changed.	Medium	●	1. Make no changes to fisheries management controls or 2. Increase the number of fishers and/or buyers reporting catch.
	No change	Ecosystem may be healthy enough to maintain historical fishing season	Medium	●	1. Make no changes to fisheries management controls.





	Increasing	Ecosystem may be healthy enough to support stronger fishing season	Low		1. Make no changes to fisheries management controls.  2. If trends have persisted for more than one year reduce limits on fishing licenses.
	Increasing	Number of fishers and/or buyers reporting catch significantly increased. This will affect CPUE and total landings trends.	Low		1. Make no changes to fisheries management controls.
	Decreasing or Increasing variability in reporting	Number of fishers and/or buyers reporting catch significantly declined.	High		1. Increase the number of fishers and/or buyers reporting catch
	Decreasing or Increasing variability in reporting	Number of fishers and/or buyers reporting catch significantly declined because external events (e.g., pandemics, environmental catastrophes,	Medium		1. Make no changes to fisheries management controls
	Decreasing or Increasing variability in reporting	Ecosystem likely not healthy enough to support historical fishing season	High		1. Limit fishing licenses





<b>Species Composition</b>	Increasing	Ecosystem may be healthy enough to support historical target species	Low	●	1. Make no changes to fisheries management controls or  2. If trends have persisted for more than one year reduce limits on fishing licenses
	Decreasing	Ecosystem likely not healthy enough to support historical target species (fewer species, more pelagic)	Medium	●	1. Limit fishing licenses
	No change	Ecosystem may be healthy enough to support historical target species	Low	●	1. Reduce limits on fishing licenses
	No change	Ecosystem may be healthy enough to support historical target species	Low	●	1. Make no changes to fisheries management controls
<b>Species Vulnerability</b>	High	Target species have high susceptibility and/or low productivity	Medium	●	1. Implement harvesting ban on vulnerable species or  2. Implement seasonal closures
	Medium	Target species have medium susceptibility medium productivity	Medium	●	1. Implement seasonal closures




	Low	Target species have low susceptibility and/or high productivity	Low		1. Reduce limits on fishing licenses
<b>Fished:Unfished Ratio</b>	Indicator >= Target	Fishing pressure appropriate for maintaining or improving the health of the ecosystem	Low		1. Make no changes to fisheries management controls or 2. If trends have persisted for more than one year reduce limits on fishing licenses
	Indicator >= Target	Unfished area has a lower density and does not represent a healthy undisturbed area (Reserve is new and has not yet led to substantial improvements in ecosystem health)	Medium		1. Ensure adequate surveillance of reserve and 2. Increase outreach on the importance of compliance with reserves
	Target > Indicator > Limit	Unfished area has a lower density and does not represent a healthy undisturbed area (Reserve is new and has not yet led to substantial improvements in ecosystem health)	Medium		1. Ensure adequate surveillance of reserve and 2. Increase outreach on the importance of compliance with reserves
	Indicator >= Target	Unfished area has a lower density and does not represent a healthy undisturbed area (Reserve is small with large amounts of species movement between fished and unfished areas)	Medium		1. Expand reserves or add additional smaller reserves





	Target > Indicator > Limit	Unfished area has a lower density and does not represent a healthy undisturbed area (Reserve is small with large amounts of species movement between fished and unfished areas)	Medium		1. Expand reserves or add additional smaller reserves
	Limit >= Indicator	High fishing pressure has caused an ecosystem state change; fishery in danger of collapse	High		1. Implement harvesting ban and/or 2. Limit fishing licenses
	Indicator >= Target	Unfished area has a lower density and does not represent a healthy undisturbed area (significant illegal fishing is occurring within the Reserve)	Medium		1. Improve enforcement of reserve. 2. Increase participatory surveillance on reserve. 3. Increase outreach to improve compliance.
	Target > Indicator > Limit	Unfished area has a lower density and does not represent a healthy undisturbed area (significant illegal fishing is occurring within the Reserve)	Medium		1. Improve enforcement of reserve. 2. Increase participatory surveillance on reserve. 3. Increase outreach to improve compliance.
	Target > Indicator > Limit	Unfished area has a lower density and does not represent a healthy undisturbed area (significant	Medium		1. Improve enforcement of reserve. 2. Increase participatory

		illegal fishing is occurring within the Reserve)			surveillance on reserve. 3. Increase outreach to improve compliance.
	Target > Indicator > Limit	High fishing pressure is putting ecosystem at risk	Medium	●	1. Limit fishing licenses
	Target > Indicator > Limit	Environmental catastrophe putting ecosystem at risk	Medium	●	1. Limit fishing licenses and/or 2. Ensure adequate surveillance of the reserves
	Indicator >= Target	Unfished area has a lower density and does not represent a healthy undisturbed area (Reserve is not optimally located)	Medium	●	1. Relocate reserve to areas with high ecological connectivity and high-quality habitat
	Target > Indicator > Limit	Unfished area has a lower density and does not represent a healthy undisturbed area (Reserve is not optimally located)	Medium	●	1. Relocate reserve to areas with high ecological connectivity and high-quality habitat
	Limit >= Indicator	Extreme environmental catastrophe has caused an ecosystem state change; fishery in danger of collapse	High	●	1. Implement harvesting ban and/or 2. Limit fishing licenses





<b>Coral Reef Thresholds</b>	Unfished biomass Indicator $\geq$ Target and Fished/Unfished biomass ratio $\geq$ Target	Fishing pressure appropriate for maintaining or improving the health of the ecosystem	Low		<p>1. Make no changes to fisheries management controls or</p> <p>2. If trends have persisted for more than one year reduce limits on fishing licenses</p>
	Unfished biomass Indicator $\geq$ Target and Fished/Unfished biomass ratio $\geq$ Target	Unfished area has a low biomass and does not represent a healthy undisturbed area (Reserve is new and has not yet led to substantial improvements in ecosystem health)	Medium		<p>1. Ensure adequate surveillance of reserve and</p> <p>2. Increase outreach on the importance of compliance with reserves</p>
	Limit $\leq$ Unfished biomass Indicator $\leq$ Target and Limit $\leq$ Fished/Unfished biomass ratio $\leq$ Target	Unfished area has a low density and does not represent a healthy virgin area (Reserve is new and has not yet led to substantial improvements in ecosystem health)	Medium		<p>1. Ensure adequate surveillance of reserve and</p> <p>2. Increase outreach on the importance of compliance with reserves</p>
	Unfished biomass Indicator $\geq$ Target and Fished/Unfished biomass ratio $\geq$ Target	Unfished area does not have comparable habitat to fished area (unfished area habitat not as healthy as fished area)	Medium		<p>1. Expand or relocate reserve</p>

Limit $\leq$ Unfished biomass Indicator $\leq$ Target and Limit $\leq$ Fished/Unfished biomass ratio $\leq$ Target	Unfished area does not have comparable habitat to fished area (unfished area habitat not as healthy as fished area)	Medium		1. Expand or relocate reserve
Unfished biomass Indicator $\geq$ Target and Fished/Unfished biomass ratio $\geq$ Target	Unfished area has a low biomass and does not represent a healthy virgin area (Reserve is small with large amounts of species movement between fished and unfished areas)	Medium		1. Expand reserves or add additional smaller reserves
Limit $\leq$ Unfished biomass Indicator $\leq$ Target and Limit $\leq$ Fished/Unfished biomass ratio $\leq$ Target	Unfished area has a low density and does not represent a healthy virgin area (Reserve is small with large amounts of species movement between fished and unfished areas)	Medium		1. Expand reserves or add additional smaller reserves
Limit $\geq$ Unfished biomass Indicator or Limit $\geq$ Fished/Unfished biomass ratio	High fishing pressure has caused an ecosystem state change; fishery in danger of collapse	High		1. Implement harvesting ban and/or 2. Limit fishing licenses

	Unfished biomass Indicator $\geq$ Target and Fished/Unfished biomass ratio $\geq$ Target	Unfished area has a low biomass and does not represent a healthy undisturbed area (significant illegal fishing is occurring within the Reserve)	Medium		<p>1. Improve enforcement of reserve.</p> <p>2. Increase participatory surveillance on reserve.</p> <p>3. Increase outreach to improve compliance.</p>
	Unfished biomass Indicator $\geq$ Target and Fished/Unfished biomass ratio $\geq$ Target	Unfished area has a low biomass and does not represent a healthy undisturbed area (significant illegal fishing is occurring within the Reserve)	Medium		<p>1. Improve enforcement of reserve.</p> <p>2. Increase participatory surveillance on reserve.</p> <p>3. Increase outreach to improve compliance.</p>
	Limit $\leq$ Unfished biomass Indicator $\leq$ Target and Limit $\leq$ Fished/Unfished biomass ratio $\leq$ Target	Unfished area has a low density and does not represent a healthy virgin area (significant illegal fishing is occurring within the Reserve)	Medium		<p>1. Improve enforcement of reserve.</p> <p>2. Increase participatory surveillance on reserve.</p> <p>3. Increase outreach to improve compliance.</p>





Limit $\leq$ Unfished biomass Indicator $\leq$ Target and Limit $\leq$ Fished/Unfished biomass ratio $\leq$ Target	Unfished area has a low density and does not represent a healthy virgin area (significant illegal fishing is occurring within the Reserve)	Medium		<p>1. Improve enforcement of reserve.</p> <p>2. Increase participatory surveillance on reserve.</p> <p>3. Increase outreach to improve compliance.</p>
Limit $\leq$ Unfished biomass Indicator $\leq$ Target and Limit $\leq$ Fished/Unfished biomass ratio $\leq$ Target	High fishing pressure is putting ecosystem at risk	Medium		1. Limit fishing licenses
Limit $\leq$ Unfished biomass Indicator $\leq$ Target and Limit $\leq$ Fished/Unfished biomass ratio $\leq$ Target	Environmental catastrophe putting ecosystem at risk	Medium		<p>1. Limit fishing licenses and/or</p> <p>2. Ensure adequate surveillance of the reserves</p>
Limit $\geq$ Unfished biomass Indicator or Limit $\geq$ Fished/Unfished biomass ratio	Extreme environmental catastrophe has caused an ecosystem state change; fishery in danger of collapse	High		<p>1. Implement harvesting ban and/or</p> <p>2. Limit fishing licenses</p>

<b>Fishing Mortality</b>	Target >= Indicator	Fishing pressure appropriate for maintaining or improving size structure of population	Low	●	<p>1. Make no changes to fisheries management controls or</p> <p>2. If trends have persisted for more than one year reduce limits on fishing licenses</p>
	Target >= Indicator	Gear shift towards more selective gear (fewer small individuals in catch)	Low	●	<p>1. Make no changes to fisheries management controls or</p> <p>2. If trends have persisted for more than one year reduce limits on fishing licenses</p>
	Limit > Indicator > Target	Strong juvenile recruitment (more small individuals entering the catch)	Low	●	<p>1. Make no changes to fisheries management controls or</p> <p>2. If trends have persisted for more than one year reduce limits on fishing licenses</p>
	Limit > Indicator > Target	Fishers targeting nursery grounds	Medium	●	<p>1. Establish reserve around nursery grounds</p>






	Limit > Indicator > Target	Gear shift towards less selective gear (more small individuals in catch)	Medium		1. Implement gear restriction (e.g., ban certain fishing gears [mesh nets, traps], restrict use of certain fishing gears [compressors, traps], modify fishing gears [decrease number of hooks in long-lines], increase mesh size).
	Limit > Indicator > Target	Gear shift towards less selective gear (more small individuals in catch)	Medium		1. Implement gear restriction (e.g., ban certain fishing gears [mesh nets, traps], restrict use of certain fishing gears [compressors, traps], modify fishing gears [decrease number of hooks in long-lines], increase mesh size).
	Indicator >= Limit	High fishing pressure negatively affecting size structure and spawning stock biomass; fishery in danger of collapse	High		1. Implement harvesting ban and/or 2. Limit fishing licenses
	Target >= Indicator	Market selectivity for larger individuals	Low		1. Implement maximum size limit and/or 2. Increase outreach about the importance of large fish to the health of the fisheries





	Limit > Indicator > Target	Market selectivity for smaller individuals	Medium	●	1. Implement minimum size limit and/or  2. Increase outreach about the importance of juvenile fish to the health of the fisheries
	Target >= Indicator	Weak juvenile recruitment (fewer small individuals entering the catch)	Medium	●	1. Implement minimum size limit and/or  2. Ensure adequate surveillance of the reserves
	Limit > Indicator > Target	Environmental catastrophe affecting size structure and spawning stock biomass	Medium	●	1. Implement minimum size limit and/or  2. Ensure adequate surveillance of the reserves
	Limit > Indicator > Target	High fishing pressure affecting size structure and spawning stocks biomass	Medium	●	1. Implement minimum size limit and/or  2. Ensure adequate surveillance of the reserves
	Limit > Indicator > Target	Emigration of large individuals from fishing area	Low	●	1. Make no changes to fisheries management controls
	Indicator >= Limit	Extreme environmental catastrophe affecting size structure and spawning stock biomass; fishery in danger of collapse	High	●	1. Implement harvesting ban and/or  2. Limit fishing licenses





	Target >= Indicator	Immigration of large individuals to fishing area	Low	●	1. Make no changes to fisheries management controls
<b>Spawning Potential Ratio</b>	Target <= Indicator	Fishing pressure appropriate for maintaining or improving size structure of population and spawning stock biomass	Low	●	1. Make no changes to fisheries management controls or 2. If trends have persisted for more than one year reduce limits on fishing licenses
	Target <= Indicator	Gear shift towards more selective gear (fewer small individuals in catch)	Low	●	1. Make no changes to fisheries management controls or 2. If trends have persisted for more than one year reduce limits on fishing licenses
	Limit > Indicator < Target	Strong juvenile recruitment (more small individuals entering the catch)	Low	●	1. Make no changes to fisheries management controls or 2. If trends have persisted for more than one year reduce limits on fishing licenses
	Limit > Indicator < Target	Fishers targeting nursery grounds	Medium	●	1. Establish reserve around nursery grounds





	Limit > Indicator < Target	Gear shift towards less selective gear (more small individuals in catch)	Medium		1. Implement gear restriction (e.g., ban certain fishing gears [mesh nets, traps], restrict use of certain fishing gears [compressors, traps], modify fishing gears [decrease number of hooks in long-lines], increase mesh size).
	Indicator <= Limit	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	High		1. Implement harvesting ban and/or 2. Limit fishing licenses
	Target <= Indicator	Market selectivity for larger individuals	Medium		1. Implement maximum size limit and/or 2. Increase outreach about the importance of large fish to the health of the fisheries
	Target <= Indicator	Market selectivity for larger individuals	Medium		1. Implement maximum size limit and/or 2. Increase outreach about the importance of large fish to the health of the fisheries





	Limit > Indicator < Target	Market selectivity for smaller individuals	Medium	●	1. Implement minimum size limit and/or  2. Increase outreach about the importance of juvenile fish to the health of the fisheries
	Limit > Indicator < Target	Market selectivity for smaller individuals	Medium	●	1. Implement minimum size limit and/or  2. Increase outreach about the importance of juvenile fish to the health of the fisheries
	Target <= Indicator	Weak juvenile recruitment (fewer small individuals entering the catch)	Medium	●	1. Implement minimum size limit and/or  2. Ensure adequate surveillance of the reserves
	Limit > Indicator < Target	Environmental catastrophe affecting size structure and spawning stock biomass	Medium	●	1. Limit fishing licenses and/or  2. Ensure adequate surveillance of the reserves
	Limit > Indicator < Target	High fishing pressure affecting size structure and spawning stock biomass	Medium	●	1. Limit fishing licenses and/or  2. Ensure adequate surveillance of the reserves

	Limit > Indicator < Target	Emigration of large individuals from fishing area	Low		1. Make no changes to fisheries management controls
	Indicator <= Limit	Extreme environmental catastrophe affecting size structure and spawning stock biomass; fishery in danger of collapse	High		1. Implement harvesting ban and/or 2. Limit fishing licenses
	Target <= Indicator	Immigration of large individuals to fishing area	Low		1. Make no changes to fisheries management controls
<b>Average Length</b>	Decreasing  Or  Limit < Indicator < Target	Emigration of large individuals from fishing area	Medium		1. Make no changes to fisheries management controls or 2. If trends have persisted for more than one-year limit fishing licenses
	Increasing  Or  Target <= Indicator	Fishing pressure appropriate for maintaining or improving size structure of population	Low		1. Make no changes to fisheries management controls or 2. If trends have persisted for more than one year reduce limits on fishing licenses

	Increasing  Or  Target $\leq$ Indicator	Gear shift towards more selective gear (fewer small individuals in catch)	Low		1. Make no changes to fisheries management controls or  2. If trends have persisted for more than one year reduce limits on fishing licenses
	Decreasing  Or  Limit $<$ Indicator $<$ Target	Strong juvenile recruitment (more small individuals entering the catch)	Low		1. Make no changes to fisheries management controls or  2. If trends have persisted for more than one year reduce limits on fishing licenses
	Decreasing  Or  Limit $<$ Indicator $<$ Target	Fishers targeting nursery grounds	Medium		1. Establish reserve around nursery grounds
	Decreasing  Or  Limit $<$ Indicator $<$ Target	Gear shift towards less selective gear (more small individuals in catch)	Medium		1. Implement gear restriction (e.g., ban certain fishing gears [mesh nets, traps], restrict use of certain fishing gears [compressors, traps], modify fishing gears [decrease number of hooks in long-lines], increase mesh size).

	Decreasing Or Indicator $\leq$ Limit	High fishing pressure negatively affecting size structure and spawning stock biomass; fishery in danger of collapse	High		1. Implement harvesting ban and/or 2. Limit fishing licenses
	Increasing Or Target $\leq$ Indicator	Market selectivity for larger individuals	Medium		1. Implement maximum size limit and/or 2. Increase outreach about the importance of large fish to the health of the fisheries
	Decreasing Or Limit $<$ Indicator $<$ Target	Market selectivity for smaller individuals	Medium		1. Implement minimum size limit and/or 2. Increase outreach about the importance of juvenile fish to the health of the fisheries
	Increasing Or Target $\leq$ Indicator	Weak juvenile recruitment (fewer small individuals entering the catch)	Medium		1. Implement minimum size limit and/or 2. Ensure adequate surveillance of the reserves

	No change  Or  Limit < Indicator < Target	Environmental catastrophe affecting size structure and spawning stock biomass	Medium		1. Limit fishing licenses and/or  2. Ensure adequate surveillance of the reserves
	Decreasing  Or  Limit < Indicator < Target	High fishing pressure affecting size structure and spawning stock biomass	Medium		1. Limit fishing licenses and/or  2. Ensure adequate surveillance of the reserves
	Decreasing  Or  Indicator <= Limit	Extreme environmental catastrophe affecting size structure and spawning stock biomass; fishery in danger of collapse	High		1. Implement harvesting ban and/or  2. Limit fishing licenses
	Increasing  Or  Target <= Indicator	Immigration of large individuals to fishing area	Low		1. Make no changes to fisheries management controls





<b>Average Trophic Level</b>	Decreasing	Fishing pressure changing to species of lower trophic level. Planktivores of lower trophic levels may be targeted in different seasons.	Medium		1. Determine what new species are being targeted. If changes are driven by planktivores (fusiliers) make no changes to fisheries management controls. If changes are not driven by planktivores, implement harvesting ban on lower trophic species or seasonal closure.
	Increasing	Fishing pressure changing to species of higher trophic level	Low		1. Determine what new species are being targeted. If these species are not vulnerable, make no changes to fisheries management controls. If species are vulnerable, implement seasonal closure.
	Increasing	Fishing pressure changing to species of higher trophic level	Medium		1. Determine what new species are being targeted. If these species are vulnerable (e.g., sharks, large groupers), implement a harvesting ban or seasonal closure.
	No change	Fishing pressure remains the same across targeted species	Low		1. Make no changes to fisheries management controls






<b>Length-based Indicators</b>	All Indicators at or better than Target ( $L_{mat} > 90\%$ , $L_{opt} > 90\%$ , $L_{mega} < 20\%$ )	Fishing pressure appropriate for maintaining or improving size structure of population and spawning stock biomass	Low	●	1. Make no changes to fisheries management controls or  2. If trends have persisted for more than one year reduce limits on fishing licenses
	Target > $L_{opt}$ > Limit and/or Target > $L_{mat}$ > Limit	Strong juvenile recruitment (more small individuals entering the catch)	Low	●	1. Make no changes to fisheries management controls or  2. If trends have persisted for more than one year reduce limits on fishing licenses
	Target > $L_{opt}$ > Limit and/or Target > $L_{mat}$ > Limit	Fishers targeting nursery grounds	Medium	●	1. Establish reserve around nursery grounds
	Target > $L_{opt}$ > Limit and/or Target > $L_{mat}$ > Limit	Strong juvenile recruitment (more small individuals entering the catch)	Low	●	1. If trends have persisted for more than one year, reduce limits on fishing licenses
	$L_{opt} < \text{Limit}$ ( $L_{opt} < 50\%$ )	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	High	●	1. Implement harvesting ban and/or  2. Limit fishing licenses





	$L_{mat} < Limit$ ( $L_{mat} < 50\%$ )	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	High	●	1. Implement harvesting ban and/or 2. Limit fishing licenses
	$L_{mega} > Limit$ ( $L_{mega} > 20\%$ )	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	High	●	1. Implement harvesting ban and/or 2. Limit fishing licenses
	$Limit > L_{mega} > Target$	Market selectivity for larger individuals	Medium	●	1. Implement maximum size limit and/or 2. Increase outreach about the importance of large fish to the health of the fisheries
	$Limit > L_{mega} > Target$	Market selectivity for larger individuals	Medium	●	1. Implement maximum size limit and/or 2. Increase outreach about the importance of large fish to the health of the fisheries
	$Target > L_{opt} > Limit$ and/or $Target > L_{mat} > Limit$	Market selectivity for smaller individuals	Medium	●	1. Implement minimum size limit and/or 2. Increase outreach about the importance of juvenile fish to the health of the fisheries

	Target > Lopt > Limit and/or Target > Lmat > Limit	Market selectivity for smaller individuals	Medium	●	<p>1. Implement minimum size limit and/or</p> <p>2. Increase outreach about the importance of juvenile fish to the health of the fisheries</p>
	Limit > Lmega > Target	Weak juvenile recruitment (fewer small individuals entering the catch)	Medium	●	<p>1. Implement minimum size limit and/or</p> <p>2. Ensure adequate surveillance of the reserves</p>
	Target > Lopt > Limit and/or Target > Lmat > Limit	Environmental catastrophe affecting size structure and spawning stock biomass	Medium	●	<p>1. Limit fishing licenses and/or</p> <p>2. Ensure adequate surveillance of the reserves</p>
	Target > Lopt > Limit and/or Target > Lmat > Limit	High fishing pressure affecting size structure and spawning stock biomass	Medium	●	<p>1. Limit fishing licenses and/or</p> <p>2. Ensure adequate surveillance of the reserves</p>
	Limit > Lmega > Target	High fishing pressure affecting size structure and spawning stock biomass	Medium	●	<p>1. Limit fishing licenses and/or</p> <p>2. Ensure adequate surveillance of the reserves</p>



	Target > Lopt > Limit and/or Target > Lmat > Limit	Emigration of large individuals from fishing area	Low	●	1. Make no changes to fisheries management controls
	Limit > Lmega > Target	Immigration of large individuals to fishing area	Low	●	1. Make no changes to fisheries management controls
<b>CPUE</b>	Increasing  Or  Indicator >= Target	Fishing pressure appropriate for maintaining or improving spawning stock biomass	Low	●	1. Make no changes to fisheries management controls or  2. If trends have persisted for more than one year reduce limits on fishing licenses
	No change  Or  Target > Indicator > Limit	Change to less efficient gear type	Low	●	1. Make no changes to fisheries management controls or  2. If trends have persisted for more than one year reduce limits on fishing licenses

	Increasing  Or  Indicator $\geq$ Target	Change to more efficient gear type	Medium		1. Implement gear restriction (e.g., ban certain fishing gears [mesh nets, traps], restrict use of certain fishing gears [compressors, traps], modify fishing gears [decrease number of hooks in long-lines], increase mesh size).
	Decreasing  Or  Limit $\geq$ Indicator	High fishing pressure negatively affecting spawning stock biomass; fishery in danger of collapse	High		1. Implement harvesting ban and/or  2. Limit fishing licenses
	Decreasing  Or  Target $>$ Indicator $>$ Limit	High fishing pressure negatively affecting spawning stock biomass due to outside fishers fishing in the managed access area	Medium		1. Improve enforcement of managed access area.  2. Increase participatory surveillance.
	Decreasing  Or  Target $>$ Indicator $>$ Limit	High fishing pressure negatively affecting spawning stock biomass due to fishing in the reserve	Medium		1. Improve enforcement of reserve.  2. Increase participatory surveillance on reserve.  3. Increase outreach to improve compliance.

	Decreasing  Or  Target > Indicator > Limit	High fishing pressure negatively affecting spawning stock biomass due to high fishing effort	Medium		1. Limit fishing licenses
	Decreasing  Or  Target > Indicator > Limit	High fishing pressure negatively affecting spawning stock biomass during spawning season	Medium		1. Limit fishing licenses
	No change  Or  Target > Indicator > Limit	Environmental catastrophe affecting size structure and spawning stock biomass	Medium		1. Limit fishing licenses and/or 2. Ensure adequate surveillance of the reserves
	Increasing  Or  Indicator >= Target	Fishers moved to less depleted fishing grounds	Medium		1. Limit fishing licenses and/or 2. Ensure adequate surveillance of the reserves
	Increasing  Or  Indicator >= Target	Fishing of spawning aggregations / hyperstability	High		1. Ban fishing of spawning aggregations.

	Decreasing  Or  Indicator $\geq$ Target	Reported catch decreasing	Medium		1. Increase number of registered fishers and buyers reporting.  2. Maintain a consistent reporting effort.
	Increasing  Or  Target $>$ Indicator $>$ Limit	Reported catch increasing	Medium		1. Make no changes to fisheries management controls.  2. Reporting effort is increasing over time due to more buyers reporting.
	No change  Or  Indicator $\geq$ Target	Reported catch decreasing	Medium		1. Increase number of registered fishers and buyers reporting.  2. Maintain a consistent reporting effort.
	Decreasing  Or  Target $>$ Indicator $>$ Limit	High fishing pressure negatively affecting spawning stock biomass due use of fishing gears that target large fish	Medium		1. Implement gear restriction (e.g., ban certain fishing gears [mesh nets, traps], restrict use of certain fishing gears [compressors, traps], modify fishing gears [decrease number of hooks in long-lines], increase mesh size).

<b>Total Landings</b>	Increasing  Or  Indicator $\geq$ Target	Fishing pressure appropriate for maintaining or improving spawning stock biomass	Low	●	1. Make no changes to fisheries management controls or  2. If trends have persisted for more than one year reduce limits on fishing licenses
	No change  Or  Target > Indicator > Limit	Fishing effort decreased	Low	●	1. Make no changes to fisheries management controls or  2. If trends have persisted for more than one year reduce limits on fishing licenses
	Decreasing  Or  Target > Indicator > Limit	High fishing pressure negatively affecting spawning stock biomass	High	●	1. Implement harvesting ban and/or  2. Limit fishing licenses
	Decreasing  Or  Limit $\geq$ Indicator	High fishing pressure negatively affecting spawning stock biomass; fishery in danger of collapse	High	●	1. Implement harvesting ban and/or  2. Limit fishing licenses

	Increasing Or Indicator $\geq$ Target	Fishing effort increased	Medium		1. Limit fishing licenses and/or 2. Ensure adequate surveillance of the reserves
	No change Or Target > Indicator > Limit	High fishing pressure negatively affecting spawning stock biomass	Medium		1. Make no changes to fisheries management controls
	Decreasing Or Target > Indicator > Limit	Reported catch decreasing	Medium		1. Increase number of registered fishers and buyers reporting. 2. Maintain a consistent reporting effort.
	Increasing Or Indicator $\geq$ Target	Reported catch increasing	Medium		1. Make no changes to fisheries management controls. 2. Reporting effort is increasing over time due to more buyers reporting.

## Step 5 – Complete Fishery Management Plan

We have provided a template as a guidance to complete a Fishery Management Plan (section 5.1 below). To complete this template, we recommend you use the outputs of the FMA Dashboard and complete a fishery management plan for each target species or a combination of target species to be managed. Note that the template provided here may should be adapted to better suit your regional context.

### 5.1 Fishery Management Plan Template

#### INTRODUCTION

Describe the purpose of the fisheries management plan. Provide a brief profile of the local government and/or managed access area site. Include location map (Fig. 1).

*[Insert map from FMA tool]*

Fig. 1 Location of the managed access area.

#### FISHERIES GOALS

Clearly state long-term objectives for fishery management under the following potential headings.

Fishery Goal	Goals
Economic	Increase yield
	Increase profit
Sustain fishery	Protect immature individuals and mega-spawners
	Protect critical habitat and spawning grounds
Food security	Increase food availability to local communities
	Increase food availability to other communities
Effective management	Increase resource availability for enforcement
	Achieve high compliance of regulations

#### FISHERY OVERVIEW

##### *History*

Provide a brief history of the fishery if available. (Catch History, Previous data, Previous Trends, Historical knowledge)

##### *Economic, Social, and Cultural Importance of the Fishery*

Provide a brief overview of economic conditions and social, cultural and economic issues.

##### *Governance*

Briefly describe the general management decision-making process. Briefly describe key legislation and regulations, as well as types of committees and zoning that are part of the decision-making process.

### *Fishery Data Collection Summary*

Determine number of fishers, buyers, vessels, and targeted species. Example below.

Participants/Species	Number	Source of Info.
Fishers estimated		Profiling
Fishers registered		Profiling
Fishers reporting through Ourfish		Ourfish
Fishers reporting through other sources		Profiling
Buyers estimated		Profiling
Buyers recording through Ourfish		Ourfish
Boats registered		Profiling
Villages in the Managed Access		Profiling
Villages reporting through Ourfish		Ourfish
Villages reporting through other sources		Ourfish
Total species reported	List of species	Ourfish

### *Top Target Species Characteristics*

Provide a brief overview of the main biological characteristics of the top (5 to 10) target species (e.g., geographic range, suitable habitat, spawning season, nursery grounds, growth rate).

Fishery Species	Geographic Range	Suitable Habitat	Nursery Ground	Spawning Season	Growth Rate
Species 1					
Species 2					
Species 3					
Species 4					
Species 5					

### *Fishing Gear, Season, and Habitat*

Describe the gear types used in the fishery (e.g., fishery targets, fixed gear, mobile gear, spear gun, etc.), as well as the season (timeframe) when the fishery occurs. Describe where the fishery occurs habitat or ecosystem fished. Example below.

Gear Type	Fishing Season	Fishing Habitat	Fishery Species
Fixed nets			
Harpoon			
Gillnets			

Handline			
Longline			
Beach seine			
SCUBA			
Freediving			
Other			

### *Current Management Regulations and Policies*

Describe existing fisheries management controls currently used to manage the fishery for each target species (e.g., seasons, catch limits, size limits, effort limits, area closures, entry limits, fishing licenses allowed, etc. Provide references of existing policy/regulation instruments (attach copies or provide links if available). Describe who implements and enforces the regulation, as well as compliance level (good, moderate, inadequate). For specific steps on fisheries management controls see **Appendix 2**.

Existing Controls	Description	Fishery Species	Policy/Regulation Instrument Ref.	Level of Compliance
Limit entry	Licensing for fishing rights in managed access area.	List species		
Catch Limit	Sets an upper limit on how many fish can be removed by a fishery in a given time.			
Bag or Trip Limit	Limits the number or weight of fish that can be landed by an individual fisher or vessel on a single day or fishing trip.			
Size Limit	Sets minimum and/or maximum bounds on the size of fish that can be legally landed in a fishery.			
Temporal Limit	Restricts the time period over which a fish can be legally landed.			
Gear Type Restriction	Restricts the type of fishing gear allowed to participate in a fishery.			
Gear Number Restriction	Places a cap on the number of gears each fisher can use.			
Sex-Specific Controls	Protect reproductively important individuals by setting sex-specific prohibitions on fishing activity.			

Seasonal Closures	Protect vulnerable life history stages by restricting the fishery during certain seasons (e.g. seasonal spawning closures).			
Protection of Ecologically Important Species	Restrict fishing of specific species to protect key ecological functions (e.g., parrotfish ban).			
Marine Reserves	Protect optimally sized areas of critical habitats (mangrove, seagrass, reef) as no fishing areas			
Breeding grounds	Protect spawning and nursery areas			
Temperature closures	Protect coral reef ecosystems during coral bleaching events			

### *Current Management Challenges*

Provide an overview of current issues in the fishery. Potential examples of management issues include:

Challenge	Description
<i>Conflict in fisheries</i>	Conflicts between fishing sectors (commercial vs artisanal), poor catch monitoring, by-catch problems, inadequate gears, illegal fishing, unreported catch.
Species vulnerability	Species listed under CITES, IUCN red listing, and any local endangered or threatened species legislation. Reference existing recovery strategies/management plans if available.
Fishing gear	Describe impact of fishing gear use on habitat (e.g., trawling, stationary nets, traps, ghost fishing, explosives)
<i>Inadequate enforcement</i>	Describe enforcement issues (lack of budget, limited enforcement staff)
Compliance level	Good (>66% compliance with all regulations), Moderated (33-66% compliance) Inadequate (<33% compliance)
<i>External threats</i>	<i>Describe external threats to the fisheries (e.g., gas and oil exploration, local pollution, shipping lines)</i>
Climate change	Describe climate change impacts on the fisheries (e.g., coral bleaching impacting suitable habitat; species moving out of the MA area due to shifting geographic ranges in response to temperature; fishers moving to new fisheries grounds.

## VULNERABILITY TO CLIMATE CHANGE

Include a summary of the Climate Change Vulnerability Assessment (CCVA), if available. The CCVA evaluates drivers of climate vulnerability based on a comprehensive set of physical, ecological and social variables. Two risk thresholds determine level of risk to climate change: *Severe-Risk* and *At-Risk*. Any variable that exceeds the *Severe Risk* threshold is considered a major driver of high vulnerability. Any variable above the *At-Risk* threshold contributes to vulnerability and can become a major driver of high vulnerability.

CCVA summary example: Climate change vulnerability in managed access area *[insert name]* is driven by high bleaching potential of the associated coral reefs, high rate of sea level rise, high susceptibility of the top three fishery species to climate change, relatively low coastal zone that may be vulnerable to flood and storm surge, lack of marine reserves, low number of community infrastructure, and relatively low level of education *[insert table]*. Recommended actions were assigned to each CCVA driver according to the level of climate change risk (see Appendix). *[Insert CCVA recommended actions table and include CCVA report as appendix]*

## FISHERIES MANAGEMENT ASSESSMENT STEPS

Provide a brief overview of the **fisheries management assessment from the FMA dashboard** including data assessment, fisheries indicator performance, interpretation of results, appropriated management controls and harvest control rules, and timeline for completion of new/ updated assessments (e.g., yearly)

### 1. Data Summary

- Data sources: OurFish, underwater visual surveys, external landing data
- Data summary by species (include data summary table from FMA Tool Step 1)

### 2. Performance Indicators

Provide a detailed description of each performance indicator and risk thresholds (reference points) used to evaluate each fisheries species or families (provided in the FMA guide). See example below.

Fisheries Species	Performance Indicator	Description	Data Source	Low Risk Threshold	High Risk Threshold
List species	Mature Fish (Pmat)	Proportion of catch above the length at first maturity ( $L_{mat}$ )	Ourfish	>90% of catch	<50% of catch
List species	Fished:Unfished Ratio	Fish biomass inside reserves	Underwater Visual Survey	Increasing or no change	Decreasing
List species	CPUE	Catch per unit effort (kg/trip)	Ourfish	Increasing or no change	Decreasing

### 3. Result Assessment

Performance Indicator 1: Length-based Indicator (Pmat: Proportion of mature fish)

- Insert figure from FMA Tool (*Step 2. Visualize Data*)
- Describe trends and how the indicator falls within low-risk and high-risk threshold
- Insert possible interpretation selection from FMA Tool (*Step 3. Interpret Results*)

Performance Indicator 2: Fished:Unfished Ratio (Fish biomass inside reserve vs outside)

- Insert figure from FMA Tool (*Step 2. Visualize Data*)
- Describe trends and how the indicator falls within low-risk and high-risk threshold
- Insert possible interpretation selection from FMA Tool (*Step 3. Interpret Results*)

Performance Indicator 3: Catch Per Unit Effort (CPUE)

- Insert figure from FMA Tool (*Step 2. Visualize Data*)
- Describe trends and how the indicator falls within low-risk and high-risk threshold
- Insert possible interpretation selection from FMA Tool (*Step 3. Interpret Results*)

### 4. Harvest Control Rules

Identify fisheries management controls and associated harvest control rules associated with possible interpretation of the assessment result for each fishery species/family and each performance indicator. For example, insert and complete the following table from the FMA Tool (*Step 3. Interpret Results*).

Performance Indicator	Fishery Species	Assessment Result	Possible Interpretation	Risk Level	Harvest Control Rule Suggested
<b>Length-based (Pmat)</b>	Species 1	Pmat > 90%	Fishing pressure appropriate for maintaining or improving size structure of population	<b>Low</b>	Make no changes to fisheries management controls
	Species 2	Pmat = 50-90%	Fishing gear designed to catch small fish	<b>Medium</b>	Increase mesh size
	Species 3	Pmat < 50%	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	<b>High</b>	Close fishery and Implement fishery recovery plan

<b>Fished:Unfished Ratio</b>	Species 1	Indicator > Target	Fishers complying with reserve	<b>Low</b>	Continue enforcement efforts
	Species 2	Target > Indicator > Limit	Significant illegal fishing is occurring within the Reserve	<b>Medium</b>	Improve enforcement of Reserve's rules and regulations.
	Species 3	Indicator < Limit	High fishing pressure has caused an ecosystem state change; fishery in danger of collapse	<b>High</b>	Close fishery and Implement fishery recovery plan
<b>CPUE</b>	Species 1	Increasing	Fishing pressure appropriate for maintaining or improving spawning stock biomass	<b>Low</b>	Make no changes to fisheries management controls
	Species 2	No change	Misreporting of effort; reported catch effort variable	<b>Medium</b>	Increase number of registered fishers and buyers reporting. Maintain a consistent reporting effort.
	Species 3	Decreasing	Fishers without a license fishing in MA	<b>High</b>	Increase participatory surveillance in fishing grounds

### 5. Complete Adaptive Fishery Management Plan

Adjust any existing and new fisheries management controls using defined harvest control rules into a management response. Describe the management response, activities, and budget associated with each management fisheries response

<b>Fishery Species</b>	<b>Management Response</b>	<b>Activities</b>	<b>Budget</b>
Species 1	Continue enforcement efforts		
Species 2	Increase mesh size		

	Improve enforcement of Reserve's rules and regulations.		
	Increase number of registered fishers and buyers reporting. Maintain a consistent reporting effort.		
Species 3	Close fishery and Implement fishery recovery plan		
	Increase participatory surveillance in fishing grounds		

## ADMINISTRATION AND IMPLEMENTING STRUCTURE

Describe the administration and implementing structure of the management plan (e.g., management board).

## MONITORING AND EVALUATION

Describe the next steps that should be taken to monitor and evaluate the fisheries management plan during the time it is effective (e.g., 1 year or 2 years).

Steps	Description
<b>Mid-time performance review</b>	Outline and evaluate performance indicators that are used to determine if the plan objectives are being met. Where applicable, include results of previous year's review to assess trend
<b>Change monitoring and data collection measures</b>	<i>Monitoring measures may include: increasing Ourfish Data collection coverage, increase fisher registration, increase number of buyers using Ourfish, improve data collection quality (counts, species info).</i>
<b>Enforcement measures</b>	<i>Enforcement measure may include: fines, sanctions, access revocations, vessel license suspensions, etc</i>
<b>Plan frequency</b>	Determine if plan should be revised after one year or after multiple years.

**Annex A:** Add copies or web links of the regulations and/or policies

**Annex B:** Add CCVA report for the area if available

## Appendix 1: Assessment Method Descriptions

### *Fishery Independent Data*

#### ***Coral Reef Thresholds***

**Description:** This method uses the ratio of total fish biomass inside a marine reserve or no-take-zone (NTZ) to the total fish biomass outside the NTZ. For coral reefs, recent studies show the existence of quantitative thresholds associated with fish biomass (measured in kg/ha). Below these thresholds, ecosystems change from desirable (e.g., high coral cover) to lesser desirable states (e.g., dominated by algae or other benthic organisms) that produce fewer ecosystem services. Fisheries in ecosystems with documented fishing thresholds can be managed to remain above these limits, reducing the risk of system collapse. At the moment, thresholds have been documented for coral reefs in the Indian Ocean (McClanahan et al. 2011) and the Caribbean Sea (Karr et al. 2014). Biomass of fished populations and unfished populations can be measured with experimental fishing or underwater visual surveys, and the resulting ratio of biomass from these surveys can then be compared to the threshold limits. Comparing this ratio to a target ratio defined in Karr et al. 2015, fishing pressure can be adjusted accordingly to maintain the fish biomass outside of a NTZ above the 0.5 BMSY (Biomass maximum multi-species sustainable yield) target.

#### **Inputs:**

- Estimate of total fish biomass inside and outside of NTZ

#### **Outputs:**

- Ratio of fish biomass outside the NTZ to the biomass inside the NTZ

#### **Management use:**

- Integrates many species into an ecosystem community metric.
- Provides a reference direction of overall fishing mortality for all species
- Provides precautionary estimate of current status of ecosystem that supports the fishery

#### **Input Sensitivities:**

- Assumes no-take reserves are representative of historical, unfished biomass

#### **Caveats:**

- This method assumes that a fully-functioning and well-enforced NTZ has been sited appropriately with representative habitat inside and outside of the NTZ, and been in place long enough for the population living inside the NTZ to be a proxy for an unfished population.

#### ***Fished/Unfished Density Ratio***

**Description:** This method uses fishery-independent data comparing ratios of density, average length density of a specific life stage (immature, mature adults, optimal size or mega-spawners), or CPUE outside to inside of no-take zones (NTZs). Babcock & MacCall (2011)

provide a clear analysis of the use of density ratio assessment methods. The density ratio control rule adjusts fishing pressure according to the distance of the ratio of density outside to inside of the NTZ from a pre-specified target ratio. One drawback of the density ratio is that in situations where populations inside and outside the reserves both crash, the ratio would remain the same and indicate that fishing can start. In the density ratio analysis, we modified the control rule to account for this dynamic. The adjustment is scaled by the overall health of the population inside the NTZ, measured as the density inside of the NTZ relative to the historic maximum density recorded in the NTZ.

**Inputs:**

- Density (or length by species) data inside and outside the NTZ (preferably collected in the same manner)
- Historical maximum density inside the NTZ

**Outputs:**

- Ratio of fish density outside the NTZ to the density inside the NTZ

**Management Use:**

- Stakeholders set a management target density ratio
- This target density ratio is compared to the ratio from assessment
- Fishing effort is adjusted based on how far apart these values are

**Input Sensitivities:**

- Assumes historical maximum density inside the NTZ

**Caveats:**

- This method assumes that a fully-functioning and well-enforced NTZ has been sited appropriately with representative habitat inside and outside of the NTZ, and has been in place long enough for the population living inside the NTZ to be a proxy for an un-fished population.
- May be less accurate for highly-mobile species that do not remain exclusively inside the NTZ such as snapper, tuna, mackerel, sharks, jacks.
- Time trends in this data can be difficult to interpret if densities inside the NTZ are changing rapidly

### ***No-take zone catch-curve (Catch Curve)***

**Description:** This method uses length-frequency data (fish lengths) from inside and outside a NTZ to compare the slope of the right-hand side of the log transformed age-frequency histogram from inside the NTZ (an estimate of natural mortality ( $M$ )) to the slope of the log transformed age-frequency histogram outside the NTZ (an estimate of total mortality ( $Z$ )). Fishing mortality ( $F$ ) can then be calculated based on the difference between these two ( $F = Z - M$ ).

**Inputs:**

- Length-frequency data inside and outside NTZ (preferably collected in the same manner)
- Life history parameters (growth parameters)

- How many years the NTZ has been established and well-enforced
- Information on the sizes of fish preferred by the fishery

**Outputs:**

- An estimate of fishing mortality ( $F$ )

**Management use:**

- Stakeholders set management target  $F/M$  based on community objectives and thresholds of risk
- Target  $F/M$  is compared with  $F/M$  from assessment
- Effort is adjusted through harvest control rules based on how far apart these values are

**Input Sensitivities:**

- Accuracy of individual fish length measurements
- Accuracy of length-at-age relationships (Von Bertalanffy growth parameters)
- Correcting fitting of the curve (sensitive to estimates of NTZ age, preferred fish size)

**Caveats:**

- This method assumes that a NTZ has been sited appropriately, well-enforced, and been in place long enough for the population living inside the NTZ to be a proxy for an unfished population
- May be less accurate for highly-mobile species that do not remain exclusively inside the NTZ, such as snapper, tuna, mackerel, sharks, jacks, etc.
- This method depends on reliably tracking population size structure changes, thus may be less accurate with small, fast-growing species

*Fishery-Dependent Data*

**Catch Trends Analyses**

**Description:** This method uses catch data to compare total catch, average catch, CPUE, and/or abundance between years of interests. Comparisons can be derived for sequential years, or as a running average between historical trends. Additionally, comparisons can be made across all species or by species of interest.

**Inputs:**

- Total catch for more than one year
- Catch-Per-Unit-Effort (CPUE) for more than one year
- Abundance of the catch for more than one year
- Length-frequency of the catch for more than one year

**Outputs:**

- Total catch and trends in total catch
- CPUE and trends in CPUE
- Abundance and trends in abundance
- Average length and trends in average length

**Management use:**

- Catch trends can support the interpretation of other analyses, for example of fishing mortality of spawning potential ratio (SPR).
- Understanding how the trends in catch fluctuate from one year to next or in comparison to the historic trends is essential to use catch trends for management.

**Input sensitivities:**

- It can be difficult to attribute a change in catch to a corresponding increase or decrease in biomass. Therefore, seeing an increase in catch could provide a false sense of security.

**Caveats:**

- This method depends on reliably tracking the total catch
- Raw CPUE is seldom proportional to abundance over a whole exploitation history and an entire geographic range, because several factors affect catch rates.

## ***Catch Curves***

**Description:** This method utilizes length-frequency data (fish lengths) to estimate the fishing mortality affecting the fished population. Total fishing mortality ( $Z$ ) is estimated using the slope of the log transformed age-frequency histogram. Fishing mortality can then be calculated based on the difference between total fishing mortality and natural mortality ( $F = Z - M$ ). Estimates of  $M$  can come from the literature.

**Inputs:**

- Length-frequency data
- Life history parameters (growth parameters)

**Outputs:**

- An estimate of fishing mortality

**Management use:**

- Stakeholders set management target  $F/M$  based on community objectives and thresholds of risk
- Target  $F/M$  is compared with  $F/M$  from assessment
- Effort is adjusted through harvest control rules based on how far apart these values are

**Input Sensitivities:**

- Accuracy of individual fish length measurements
- Accuracy of length-at-age relationships (Von Bertalanffy growth parameters)
- Correcting fitting of the curve (i.e., preferred fish size)

**Caveats:**

- This method depends on reliably tracking population size structure changes, thus may be less accurate for small, fast-growing species

## ***Froese Sustainability Indicators***

**Description:** This method uses the length-frequency of the catch and life history growth parameters to estimate the distribution of life stages in the catch (Froese 2004, Cope and Punt 2009), and subsequently whether or not the catch is sustainable.

**Inputs:**

- Length-frequency of the catch
- Length at maturity
- Natural mortality
- Von Bertalanffy growth parameters

**Outputs:**

- This method first calculates three metrics of fisheries sustainability:
  - (i) percentage of mature fish in catch, with 100% as target;
  - (ii) percentage of specimens with optimum length in catch ( $L_{opt}$ ), with 100% as target;
  - (iii) percentage of ‘mega-spawners’ in catch
- Using these three metrics and the life history parameters, the method next uses a decision tree to determine whether or not spawning biomass is greater or less than a sustainable target reference point.

**Management use:**

- By fishing at  $L_{opt}$  or by fishing mature individuals that have “spawn-at-least-once” in conjunction with the protection of megaspawners, sustainability of the fishery can be maintained.
- If this method determines spawning biomass is less than the TRP, adjustments in management may be necessary

**Input sensitivities:**

- Accuracy of individual fish length measurements
- Accuracy of length at maturity
- Selectivity

**Caveats:**

- This method depends on reliably tracking population size structure changes
- May be less accurate with small, fast-growing species

### **Mean Length ( $L_{bar}$ )**

**Description:** This method uses fishery-dependent or independent length-frequency data.  $L_{bar}$  uses the minimum and maximum fished sizes, and the average length of the fish within the fished sizes from a fished population, along with growth parameters. In the Ault et al. 2005 model,  $L_{bar}$  provides an estimate of fishing mortality ( $F$ ) that can be compared to an estimate of natural mortality ( $M$ ). Increasing fishing pressure will often cause decreasing average length.

**Inputs:**

- Fishery-dependent or fishery-independent length-frequency data of fished population
- Life history parameters, growth parameters, and natural mortality ( $M$ )

- Information on the sizes of fish preferred by the fishery

**Outputs:**

- An estimate of fishing mortality ( $F$ )

**Management use:**

- Stakeholders set management target  $F/M$  based on community objectives and thresholds of risk
- Target  $F/M$  is compared with  $F/M$  from assessment
- Effort is adjusted based on how far apart  $F/M$  from the assessment is from the  $F/M$

**Input sensitivities:**

- Estimate of  $M$  and growth parameters
- Accuracy of individual fish length measurements

**Caveats:**

- This method depends on reliably tracking population size structure changes
- May be less accurate with small, fast-growing > species
- $M$  is assumed to be known, which often it is not
- Assumes equilibrium
- This model is less reliable when mean fish length is very low

## **Mean Weight**

**Description:** This method can use fishery-dependent or independent weight-frequency data to estimate fishing mortality ( $F$ ) when no size structure data is available. This method requires the von Bertalanffy growth function, as well as the length-weight relationship and the natural mortality ( $M$ ). In this method, we construct a Yield-Per-Recruit (YPR) model, which allows us to estimate the theoretical age and weight structure of the population at any size. Similar to Mean Length ( $L_{bar}$ ), Mean Weight provides an estimate of  $F$  that can be compared to an estimate of  $M$ . Increasing fishing pressure will often cause decreasing average weight.

**Inputs:**

- Fishery-dependent or fishery-independent weight-frequency data
- Life history parameters, growth parameters, natural mortality ( $M$ )
- Information on the sizes of fish preferred by the fishery

**Outputs:**

- An estimate of fishing mortality ( $F$ )

**Management use:**

- Stakeholders set management target  $F/M$  based on community objectives and thresholds of risk
- Target  $F/M$  is compared with  $F/M$  from assessment
- Effort is adjusted based on how far apart these values are

**Input Sensitivities:**

- Estimate of  $M$  and growth parameters
- Accuracy of individual fish weight measurements
- Accuracy of length-weight relationship

**Caveats:**

- This method depends on reliably tracking population size structure changes
- May be less accurate for small, fast-growing species
- $M$  is assumed to be known, which often it is not
- Assumes equilibrium
- This model is less reliable when mean fish weight is very low

### ***Bounded Mean Length Mortality Estimator***

**Description:** A modification of the Mean Length ( $L_{bar}$ ) method (Ehrhardt et al. 1992). Does not assume that fishing mortality has been constant over the life span of the fish being assessed. It considers the time since a management change, and restricts the data used for this analysis to those fish which have recruited to the fishery during this time period.

**Inputs:**

- Length-frequency of the catch, since management change
- Mean asymptotic length (cm) of the von Bertalanffy growth equation
- $L$ , the age at  $L_c$  (using the von Bertalanffy equation) and adding the number of years since a known harvest rate policy change, then converting back to length
- $L_{bar}$  is the mean length of fish between  $L_c$  and  $L$ .

**Outputs:**

- An estimate of fishing mortality ( $F$ )

**Management use:**

- Stakeholders set management target  $F/M$  based on community objectives and thresholds of risk
- Target  $F/M$  is compared with  $F/M$  from assessment
- Effort is adjusted based on how far apart these values are

**Input Sensitivities:**

- Estimate of  $M$  and growth parameters
- Accuracy of individual fish length measurements

**Caveats:**

- This method depends on reliably tracking population size structure changes
- May be less accurate for small, fast-growing species
- $M$  is assumed to be known, which often it is not
- Assumes equilibrium
- This model is less reliable when mean fish length is very small

## ***Length-based Spawning Potential Ratio (LBSPR)***

**Description:** Length-based Spawning Potential Ratio (LBSPR) method uses length-frequency data from a fished population to calculate the spawning potential ratio (SPR) of a fishery (Hordyk et al. 2014). This method is based on the concept that the equilibrium unfished size structure of a population depends on the average maximum size attained and the ratio of the rate of natural mortality ( $M$ ) to the individual growth rate ( $K$ ) (Prince et al. 2014). SPR is a measure of current egg production relative to maximum possible production at unfished levels. Unfished egg production is estimated using the natural mortality ( $M$ ), Von Bertanaffy (VBK) growth parameters, age at first maturity, and fecundity at age. The fished SPR is calculated using the same parameters, along with estimates of the fishing mortality rate ( $F$ ), and the sizes of fish selected by the fishery.

By comparing the estimated current SPR with a target SPR defined by stakeholders, a harvest control rule can be used to adjust fisheries management controls accordingly.

### **Inputs:**

- Length-frequency data from a fished population
- Gear selectivity
- Life history parameters (fecundity, VBK parameters, natural mortality, age-at-maturity, length at age relationships)

### **Outputs:**

- SPR of target species

### **Management use:**

- Stakeholders set management target SPR
- Target SPR is compared to SPR from assessment
- Effort is adjusted based on how far apart these values are

### **Input Sensitivities:**

- Accuracy of individual fish length measurements
- Representativeness of the length data
- Accuracy of life history information, particularly growth and maturity parameters

### **Caveats:**

- This method is dependent on reliably tracking changes in population size structure
- May be less accurate for small, fast-growing species
- Assumes the fishery is in equilibrium and that conditions are relatively stable (environmental conditions, fishing pressure, stock status, etc.)
- This method is less accurate if fishing pressure has been changing dramatically year to year
- This method is less effective for species with highly variable recruitment (addition of juveniles to the population) such as lobster

## Appendix 2: Determine Appropriate Fisheries Management Controls

### A2.1 – Summarize and qualitatively assess any existing fisheries management controls

Summarize any existing fisheries management controls (FMCs) that may affect your site. If there are no existing FMCs, skip to section A2.2.

Qualitatively assess how existing fisheries management controls are performing. This will help determine whether or not these controls are appropriate, or if other or additional controls should be used instead. Consider the following:

- Who mandates this FMC? Is it locally mandated (i.e., it could potentially be modified), or is it mandated by a higher body (e.g., regional or national body – this may make the FMC more difficult to modify)?
- What is the cost of this FMC? Does it require expensive data collection or enforcement?
- What is the level of compliance with this FMC? (e.g., none, low, medium, high)
- What is public attitude towards this FMC? (e.g., approve, ambivalent, disapprove)
- Are current FMCs helping the fishery reach its goals? You may use Table A2.1-A2.3 to see common goals of many FMCs and determine if the goals of your fishery are being met.
- What are other implementation pros/cons?

Based on this qualitative assessment, you may be happy with the current set of FMCs in which case you can skip to **A2.3**. Alternatively, if the FMCs are not performing as your community may wish or no FMCs exist, proceed to **A2.2** to select different or new FMCs.

Quantitatively assess how well existing FMCs are doing in terms of fisheries performance indicators by performing data-limited assessments using any available data. Based on this quantitative evaluation, you may wish to change FMCs during the next iteration of the FMA cycle.

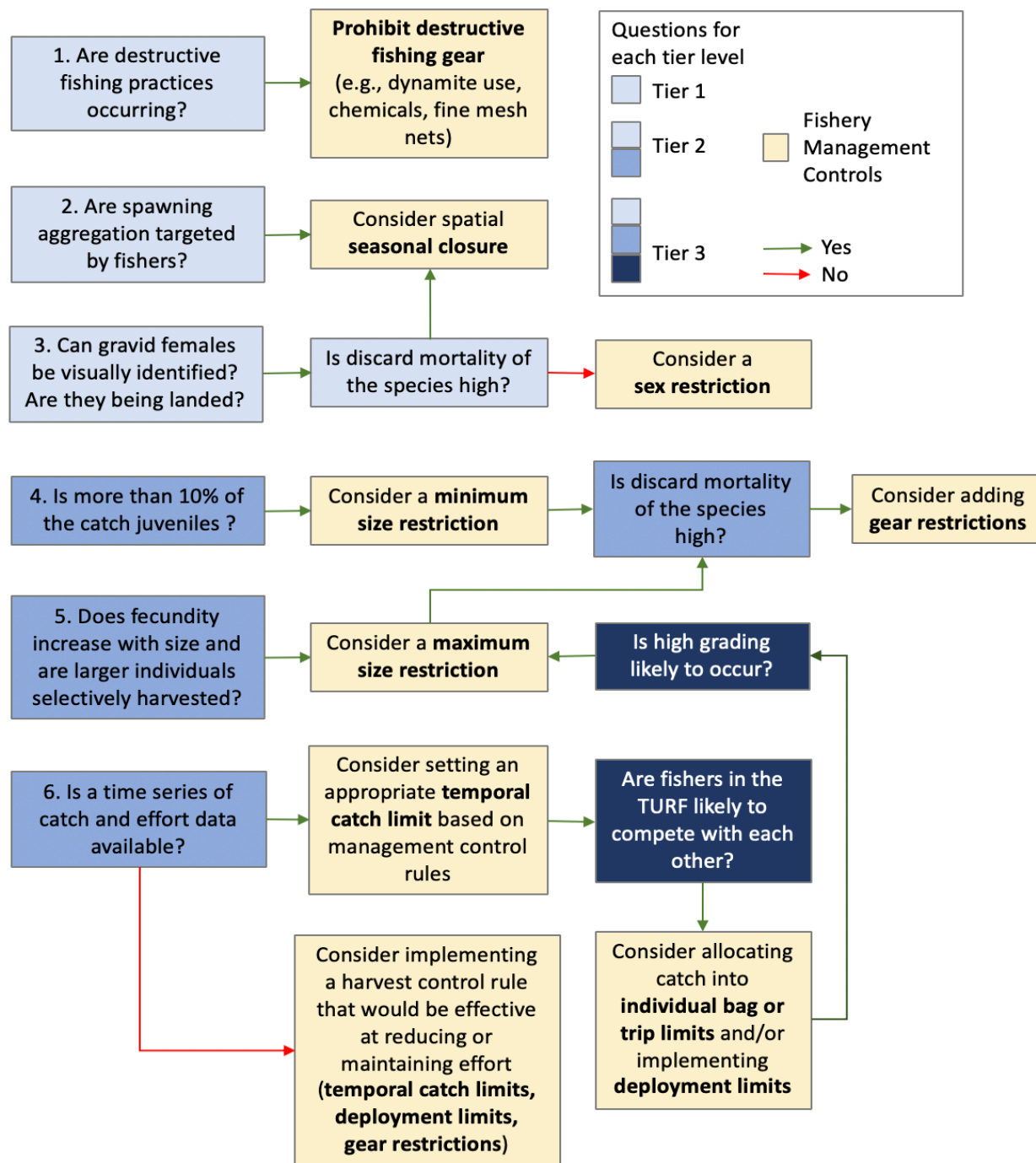
### A2.2– Determine preliminary new fisheries management controls

There are several fisheries management controls (FMCs) to address fishery goals. Many FMCs are designed with the primary objective of limiting fishing mortality (e.g., limiting number of fishing licenses). Other FMCs are designed to protect certain biological or ecological functions in an ecosystem (e.g., seasonal closures to protect spawning aggregations).

Descriptions, data requirements, and enforcement considerations for the implementation of commonly used FMCs are listed below. Additionally, we present [case studies](#) for each FMC that describe situations where the FMC has been implemented in a small-scale fishery (see section **A2.6**). These case studies demonstrate opportunities, challenges, and implications these different FMCs bring to small-scale fisheries.

To select a list of adequate fisheries management controls, use the six questions in the decision tree below (**Figure A2.1**) as a general guide to determine what FMCs may be most

appropriate for your fishery. Community goals for management and conditions occurring in your fishery must also be carefully considered. This figure helps selecting the type of appropriate FMC (e.g., minimum size limit), but follow the steps 4c and 4d to determining specific FMCs for the target species (e.g., minimum size limit of 30 cm TL).



**Figure A2.1.** Decision tree to help identify appropriate Fisheries Management Controls. Tier 1: Precautionary assessment and management. Tier 2: Preliminary adaptive assessment and management. Tier 3: Multi-indicator framework for adaptive assessment and management

**Table A2.1** Descriptions and implementation considerations for different fisheries management controls

<b>Fishery Management Control</b>	<b>Primary Objective</b>	<b>Minimum data requirement</b>	<b>Enforcement</b>
<b>Catch Limit</b>	Limit fishing mortality	A time series of catch and effort data; information on the stock's productivity (length-based DLSA methods can be used for proxies); life history information	Catch limits (individual or group allocated) can be enforced if landings are relatively centralized but may be more difficult if landing sites are more dispersed. Any catch limit program will have associated monitoring costs for implementation to be effective.
<b>Bag or Trip Limit</b>	Limit fishing mortality	Time series of catch and effort data, information on the stock's productivity (length-based DLSA methods can be used for proxies), and total number of fishermen participating in a fishery.	Can be enforced if landings are relatively centralized but may be more difficult if landing sites are more dispersed. Monitoring for every vessel or individual in a fishery will result in significant implementation costs.
<b>Size Limit</b>	Limit fishing mortality	Size at maturity and/or size of megaspawners; discard mortality rates for targeted species are helpful	Can be enforced if landings are relatively centralized but may be more difficult if landing sites are more dispersed. Monitoring is straightforward and does not have many associated implementation costs
<b>Temporal Limit</b>	Limit fishing mortality	Temporal dynamics of fishing effort; temporal characteristics or behavior of target species; information on the relationship between catch and effort is helpful.	Can be enforced if landings are relatively centralized but may be more difficult if landing sites are more dispersed. Monitoring is straightforward and does not have many associated implementation costs.
<b>Gear Restrictions – Gear Type</b>	Limit fishing mortality	Information on the relationship between gear characteristics, fishing effort, and selectivity. If only banning destructive fishing gear, no data is required.	Relatively easy to enforce however, gathering information required for an effective implementation can be costly. If only banning destructive fishing gear, there are low upfront costs but ongoing monitoring costs should be considered.

<b>Gear Restrictions – Gear Number</b>	Limit fishing mortality	Current fishing effort levels in terms of number of gears; information on the relationship between catch and effort is helpful	The ease and cost of enforcement will depend on how easily fishing gears can be observed.
<b>Sex-Specific Controls</b>	Limit fishing mortality	Information on reproductive traits and sex ratios	Sex-specific controls are straightforward to enforce if there are obvious differences between the sexes. Monitoring costs will depend on how easily the catch can be observed.
<b>Seasonal Closures to Protect Vulnerable Life History Stages</b>	Protect vulnerable life history stages	Information on seasonal behavior such as spawning aggregations and migrations, and the temporal and spatial variability of these behaviors.	Can be enforced if landings are relatively centralized but may be more difficult if landing sites are more dispersed. Seasonal closures are more straightforward to monitor if the closure covers all species, but may be more difficult if the closure only covers a certain species in the fishery.
<b>Protection of Ecologically Important Species</b>	Protect ecological function	Information on ecological interactions and roles.	Protection of ecologically important species can be straightforward but monitoring costs will depend on how easily the species and fishery catch can be observed.

## Descriptions of fisheries management controls

**Catch Limit:** Sets an upper limit on how many fish can be removed by a fishery in a given time. This can be for an entire fishery or can be allocated to individuals or groups of individuals (e.g., a fisher association). Limits can be set for individual species or groups of species (also known as a “quota basket”). If set correctly and fishers’ incentives are aligned, catch limits are the most direct way of managing fishing mortality. Catch limits can be set on the species basis but also aggregate level based on similar life history traits and vulnerability. If the incentives are not aligned and rights are not allocated, catch limits can perpetuate the race to fish that may lead to safety issues and destructive fishing practices (e.g., gear lost, high grading, etc.)

**Bag or Trip Limit:** Limits the number or weight of fish that can be landed by an individual fisher or vessel on a single day or fishing trip. If no illegal discarding is occurring, then bag limits and trip limits based on number of fish allowed to catch can directly control fishing mortality. Can perpetuate high grading and illegal discarding.

**Size Limit:** Sets minimum and/or maximum bounds on the size of fish that can be legally landed in a fishery. Size limits can protect age-structure by controlling the size selectivity of the fishery to ensure fish have the opportunity to spawn before being caught. However, the

biology of the species must be considered carefully because size limits can result in unintended, negative consequences. Size limits don't directly control fishing mortality and may cause size truncation over time by removing the largest individuals from a fisher.

**Temporal Limit:** Restricts the time period over which a fish can be legally landed. If fishing mortality doesn't increase before or after the closure, temporary closures allow marine resources to increase without disturbance to ensure fish grow bigger and new recruits enter the fishery. Perpetuates the race to fish before and after the closure. Increases fishing effort before and after the closure. Doesn't directly manage fishing mortality.

**Gear Restrictions – Gear Type:** Restricts the type of fishing gear allowed to participate in a fishery (including banning destructive fishing gear such as dynamite, cyanide, and fine mesh nets) but doesn't directly manage fishing mortality.

**Gear Restrictions – Gear Number (also known as Deployment Limits):** Places a cap on the number of gears each fisher can use (such as the number of fixed traps or the number of hooks on a line). Does not directly manage fishing mortality. Can reduce the number of fishing gears in the water thus decreasing habitat impacts.

**Sex-Specific Controls:** Protect reproductively important individuals by setting sex-specific prohibitions on fishing activity.

**Seasonal Closures to Protect Vulnerable Life History Stages:** Protect vulnerable life history stages by restricting the fishery during certain seasons. Seasonal spawning closures allow spawning to occur without disruption to ensure recruits enter the fishery. Perpetuates the race to fish before and after closure. Increases fishing effort before and after the closure. Doesn't directly manage fishing mortality.

**Protection of Ecologically Important Species:** Restrict fishing of specific species in order to protect key ecological functions. Does not directly control fishing mortality.

### **A2.3 – Consider applying additional fisheries management controls**

Appropriate FMCs will depend on the specific conditions and characteristics of the fishery and surrounding community. The following 6 steps, along with the information in **Table A2.1-A2.3**, can serve as a guide to help identify a set of FMCs that when combined may be effective at meeting your site's management goals.

1. Find the FMC(s) that were either existing (Step 3a) or newly selected (Step 3b) in **Table A2.1-A2.3**. These tables describe potential negative or positive impacts of each FMC on common biological, ecological, and socioeconomic fishery management objectives.
2. Identify which of the management objectives (e.g., biological, ecological, or socioeconomic) align with your site's management goals.
3. Review the potential impact of each FMC being considered for your site on each of your management objectives.
4. Determine if selected FMC(s) will conflict with or fail to accomplish any of your site's management goals (e.g., a catch limit may result in an increase in bycatch and increased habitat damage if implemented without any other FMCs).

5. Use **Table A2.2-A2.3** to identify FMC(s) that are associated with positive impacts on the site management objectives and that in combination with previously selected FMCs can meet multiple management objectives (e.g., combining catch limits with gear restrictions may be effective at controlling harvest, and reducing bycatch and habitat damage).
6. Determine the most appropriate FMC(s) for your site (use **Table A2.2-A2.3**) by considering the “ease of implementation” for each FMC listed in section A2.1 and how it aligns with the specific conditions and characteristics the site.

## **A2.4 – Consider implications of FMCs with relevant stakeholders**

Before deciding which FMCs will be implemented at your site, consider how fishers and other stakeholders (e.g., middlemen, enforcement organizations, etc.) may respond to these FMCs by answering the following questions:

1. What management controls have successfully been implemented in the past?
2. Can this management control(s) be effectively implemented and enforced?
3. Is this method socially and politically feasible, and will fishers comply with it?

Discuss with all relevant stakeholders whether the selected FMCs can meet the stated community objectives along with any potential tradeoffs of implementing the selected FMC(s).

Any existing social survey data can be used to provide insight into individual attitudes towards fishery management in your community. Any information on enforcement should also be reviewed to gain a better understanding of the likelihood of compliance with implementation of new FMCs.

## **A2.5 – General guidance for setting effective FMCs for the first time**

Use this step when developing an Adaptive Fisheries Assessment and Management Framework for the first time. In following years, you will use harvest control rules (defined later) to adaptively adjust these initial controls.

After finalizing the list of FMCs, define the specifics of the FMC for the first time (e.g., specify catch limit). The specifics will depend on the status of your site’s resources, the population dynamics of the targeted species at the site, and your site’s specific management objectives.

If you believe target species are depleted, if little information is available, and/or if enforcement or compliance is low, we recommend taking a precautionary approach using the following suggestions:

- **Catch Limit** - Set annual catch limit at or below the previous year’s total catch.

- **Bag or Trip Limit** - Divide the previous year's catch by the number of fishers participating in the fishery. Set the bag or trip limit at that level or below.
- **Size limit** - Set a minimum size limit above the minimum size at maturity. A maximum size limit may also be set to protect mega-spawners.
- **Temporal limits** – Close the fishery during biologically sensitive times (e.g., spawning season) or during in areas when the catchability of species greatly increases (e.g., spawning aggregations).
- **Vessel/gear restrictions** – Set vessel and gear restrictions to minimize the impact of the fishery on habitat. Set gear dimensions to reduce bycatch (e.g., prohibit small mesh size in nets to reduce landings of unmatured individuals).
- **Deployment limits** - Initial deployment limits may be set to restrict the number of gears being used to the same number of gears that were used in the previous year or below.
- **Sex specific** - Ban the take of females that are egg-bearing or the take of females during a biologically sensitive period.
- **Protection of ecologically important species** - Restrict fishing of specific species to protect key ecological function (e.g., herbivorous parrotfish that control algae cover).

**Table A2.2** Effectiveness of different fisheries management controls in meeting biological and ecological objectives.

Fisheries Management Control	Biological Objectives			Ecological Objectives	
	Protect Spawning Stock Biomass (SSB)	Protect Age-Structure	Protect Vulnerable Life History Stages (VLS)	Protect Habitat	Reduce Bycatch and/or Discards
<b>Catch Limit</b>	Directly protect SSB	Do not directly protect age-structure and may have a negative impact on the age-structure because fishers are choosing an overall quantity indiscriminate of size or age.	Do not directly protect vulnerable life history stages	Do not protect habitat and may have a negative impact on habitat unless the use of excessive gear that could damage habitat is mitigated by an individual allocation that stops the race to fish.	Bycatch can often increase under a catch limit if there is not a limit for bycatch species along with target species and/or if a single-species catch limit has been reached in a multi-species fishery.
<b>Bag or Trip Limit</b>	Do not directly protect SSB because an increase in total fishing effort can still occur	Do not directly protect age-structure and may incentivize fishers to choose larger and more valuable fish than they would otherwise catch, which may have a negative impact on age structure.	Do not directly protect vulnerable life history stages	Do not directly protect habitat	Often result in an increase in bycatch and/or discards because of the incentives to catch the largest and highest value fish, and/or if a single-species catch limit has been reached in a multi-species fishery

<b>Size Limit</b>	Do not directly protect SSB because they do not control total harvest of a stock	Can protect age-structure by controlling the size selectivity of the fishery if discard mortality rates are low. However, the biology of the species must be considered carefully because size limits can result in unintended, negative consequences such as size structure truncation.	May protect vulnerable life history stages if those stages are associated with a certain size.	Do not directly protect habitat	Bycatch and/or discards can increase under a size limit because under- or over-sized individuals must be discarded. High discard mortality rates can result in size-limits having unintended, negative consequences. Discard mortality may be less of a problem for invertebrates.
<b>Temporal Limit</b>	Do not directly protect SSB because they do not control total harvest of a stock	Do not protect age-structure and may have a negative impact on the age-structure because fishers may race to catch as much fish as they can, while they can, indiscriminate of size or age.	Can be designed to protect vulnerable life history stages associated with the timeframe of the limit.	Do not protect habitat and may have a negative impact if excessive gear is set during the race-to-fish and is lost or abandoned	Can be designed to reduce bycatch if a fishery interaction with a bycatch species is seasonal. Temporal limits not designed to reduce bycatch may cause an increase in bycatch because fishers are less selective during the race-to-fish
<b>Gear Restrictions – Gear Type</b>	Do not directly protect SSB because they do not control	Can be implemented to protect age-structure by modifying selectivity to allow	May protect vulnerable life history stages	Do not directly protect habitat but can be designed to reduce the	May reduce bycatch by improving selectivity in a fishery

	total harvest of a stock	individuals of a specific size to escape harvest.		impact a fishery has on habitat	
<b>Gear Restrictions – Gear Number</b> (also known as Deployment Limits)	Do not directly protect SSB because an increase in effort may occur if new fishers join the fishery	Do not directly protect age structure	Do not directly protect vulnerable life history stages	Do not directly protect habitat	Do not directly reduce bycatch
<b>Sex-Specific Controls</b>	Protect the spawning biomass of the sex targeted by the regulation	Do not protect age-structure and may have negative consequences for age-structure because fishers may target the largest individuals of the sex that is not protected	May protect a vulnerable life stage if that occurs for a specific sex	Do not directly protect habitat	Can increase discards because individuals of the protected sex must be returned to sea and depending on the species may not survive
<b>Seasonal Closures to Protect Vulnerable Life History Stages</b>	Protect spawning biomass during specific seasons	Do not directly protect age-structure	Protect seasonal vulnerable life history stages	Do not directly protect habitat and may have a negative impact on habitat if excessive gear is set during the race-to-fish and is lost or abandoned	Do not reduce bycatch and can increase bycatch and discards during the race to fish
<b>Protection of Ecologically</b>	Protects the SSB of the species	Protects the age-structure of the	Does not directly protect	May protect the habitat if the species	Can increase discards because

<b>Important Species</b>	of interest but does not directly protect SSB of other target species	protected population but does not directly protect age-structure of other target species	vulnerable life history stages	of interest plays an important role in maintaining ecosystem health	individuals of the protected species can be discarded to avoid enforcement penalties.
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**Table A2.3** Effectiveness of different fisheries management controls in meeting socio-economic objectives

<b>Fisheries Management Control</b>	<b>Increase Fisher Profits</b>	<b>Increase Product Quality</b>	<b>Maintain Fishing Efficiency</b>	<b>Fish</b>
<b>Catch Limit</b>	Catch limits that are not allocated at an individual level often cause a short-term decrease in fisher profits because the race-to-fish incentivizes capital stuffing and may cause market flooding. Once a depleted stock recovers, there may be a long-term increase in fisher profits. Effects from the race-to-fish and capital stuffing may be reduced in the case of individually allocated limits.	If market flooding occurs, product may be frozen or spoil, decreasing the product value. Eliminating market flooding by eliminating the race-to-fish through individual allocation of catch limits can increase product quality.	Do not directly impact short-term fishing efficiency. Individual allocation of catch limits can increase fishing efficiency as the race-to-fish is stopped and fishers have more control over when to fish. Once a depleted stock recovers, there may be a long-term increase in fishing efficiency.	May imp fish the may eve con uns allo limi pos fish can to-f
<b>Bag or Trip Limit</b>	Often cause a short-term decrease in fisher profits, because fishers are incentivized to take more trips to maintain landings, increasing fishing costs. Once a depleted stock recovers, there may be a long-term increase in fisher profits.	Product quality may increase under bag or trip limits because there is an incentive to catch the biggest and highest value/quality fish.	Do not directly impact short-term fishing efficiency. Once a depleted stock recovers, there may be a long-term increase in fishing efficiency.	May imp incr of f that fish
<b>Size Limit</b>	Do not increase short-term fisher profits and may cause a decrease in landings revenue if a large portion of landings is over or undersized and needs to	Can be implemented to increase product quality if the quality of the product is related to its size.	Do not directly impact short-term fishing efficiency. Once a depleted stock recovers, there may be	Do imp safe

	be discarded. Once a depleted stock recovers, there may be a long-term increase in fisher profits.		a long-term increase in fishing efficiency.	
<b>Temporal Limit</b>	Fishers often begin targeting other, less valuable species when a fishery is closed due to a temporal limit, causing short-term fisher profits to decrease. Once a depleted stock recovers, there may be a long-term increase in fisher profits.	Fishers often become less selective during the race-to-fish, resulting in a decrease in product quality	Do not directly impact short-term fishing efficiency. Once a depleted stock recovers, there may be a long-term increase in fishing efficiency.	May impact fishery the commercial fisher become
<b>Gear Restrictions – Gear Type</b>	Incentivize fishers to invest and improve in unregulated dimensions of gear, increasing fishing costs and reducing short-term fisher profits. Once a depleted stock recovers, there may be a long-term increase in fisher profits.	Can be designed to increase product quality in a fishery by improving selectivity of higher value individuals	Reduce short-term fishing efficiency. Once a depleted stock recovers, there may be a long-term increase in fishing efficiency.	Do directly safe des that unin imp as c
<b>Gear Restrictions – Gear Number</b> (also known as Deployment Limits)	Do not directly impact short-term profits but may help stabilize fishing costs. Once a depleted stock recovers, there may be a long-term increase in fisher profits.	Do not have an impact on product quality	May reduce short-term fishing efficiency. Once a depleted stock recovers, there may be a long-term increase in fishing efficiency.	Do imp
<b>Sex-Specific Controls</b>	May decrease short-term fisher profits because a portion of the catch must be discarded. Once a depleted stock recovers, there may be a long-term increase in fisher profits.	Do not affect product quality unless quality is related to sex	Do not directly impact short-term fishing efficiency. Once a depleted stock recovers, there may be a long-term increase in fishing efficiency.	Do imp
<b>Seasonal Closures to Protect Vulnerable</b>	Do not increase short-term fisher profits and may cause a decrease in income because fishers often shift to less valuable	Can lead to a decrease in product quality as fishers shift to less desirable species	Do not directly impact short-term fishing efficiency. Once a depleted stock recovers, there may be	May imp bec rac

Life History Stages	species. Once a depleted stock recovers, there may be a long-term increase in fisher profits.		an additional long-term increase in fishing efficiency.	may con
<b>Protection of Ecologically Important Species</b>	Will decrease short-term fisher profits. Once ecological function improves and other depleted target stocks recover, there may be a long-term increase in fisher profits.	May increase the product quality of other target species if the protected species is prey for the target species	Does not directly impact short-term fishing efficiency. Once a depleted stock recovers, there may be an additional long-term increase in fishing efficiency.	Doe imp

## A2.6 Fisheries Management Control Case Studies

### *Catch Limits*

In the sea cucumber fishery in the Northern District of New Caledonia, fishermen noticed a decline in commercial sized sea cucumber known as sandfish (*Holothuria scabra*) in the early 2000s. After closing the fishery for a short period of time, they worked with the Fisheries Department in 2008 to set a total allowable catch (TAC) for the fishery, which they then allocated into quotas for individual fishermen. The TAC was set according to the total biomass of legally-sized adult sandfish, considering both abundance and body size. This harvestable biomass was calculated through sampling of the sandfish population and was re-assessed periodically. After implementing the TAC, there was an increase in total sandfish biomass and a 142% increase in the number of individuals. There was also an increase in the mean weight of sandfish and the density of individuals. Due to the increases in the sandfish population, the fishermen were able to raise the TAC in subsequent years. They also combined the use of the TAC with a cycle of open and closed periods of fishing.

Leopold, M., Cornuet, N., Andrefouet, S., Moenteapo, Z., Duvauchelle, C., Raubani, J., Ham, J., & Dumas, P. (2013). *Comanaging small-scale sea cucumber fisheries in New Caledonia and Vanuatu using stock biomass estimates to set spatial catch quotas*. [Environmental Conservation 40\(4\), 367-379](#).

### *Bag/Trip Limits*

In the recreational gag (*Mycteroperca microlepis*) fishery in the Gulf of Mexico, bag limits are used to prevent recruitment overfishing. However, discard mortality rates reduce the efficiency of the fishery.

Tetzlaff, J.C., Pine, W.E., Allen, M.S., & Ahrens, R.N.M. (2013). *Effectiveness of size limits and bag limits for managing recreational fisheries: a case study of the Gulf of Mexico recreational gag fishery*. [Bulletin of Marine Science 89\(2\), 483-502](#).

### *Size Limits*

1. In Puerto Rico's spiny lobster (*Panulirus argus*) fishery, landings, catch per unit effort, and average body size all increased from 1988-2001, potentially as a result of the implementation of a minimum size limit (Matos-Caraballo et al., 2007).

Matos-Caraballo, D. (2007). Overview of Puerto Rico's small-scale fisheries statistics 2001-2004. [Proceedings of the Gulf and Caribbean Fisheries Institute 58: 95–106.](#)

2. Belize's queen conch fishery is managed by a variety of regulations, including a prohibition on fishing with scuba equipment, marine reserves that protect nursery, feeding, and mating grounds, a quota system, and a minimum size limit. The minimum size limit was introduced in 2000 and establishes a minimum shell length of 7 inches and a minimum weight of 3 ounces of partially processed meat. As a result of these regulations, conch landings increased from 1977 to 2011, as have average conch density and mean shell length. The minimum size was set based on the size at maturity.

Gongora, M. (2012). Belize National Conch Report 2012. CFMC/OSPESCA/WECAFC/CRFM Queen Conch Working Group Meeting. Panama City, Panama, 23 October 2012.

Gongora, M., & Carcamo, R. (). Belize. In: Regional Workshop on the Monitoring and Management of Queen Conch, *Strombus gigas*. [FAO Fisheries Report 832. Kingston, Jamaica. pp. 66-76.](#)

Huitric, M. (2005). Lobster and conch fisheries of Belize: a history of sequential exploitation. [Ecology and Society 10\(1\), 21.](#)

### **Temporal Limits**

1. On Ahus Island in Papua New Guinea, the community only allows fishing in six specific areas of their lagoon for a certain number of days each year. The locations of the restricted areas are dictated by tradition. Ecological surveys found that the biomass and average size of target species was much greater in the restricted areas than outside, and harvest days did not affect the overall stock.

Cinner, J.E., Marnane, M.J., & McClanahan, T.R. (2005). Conservation and community benefits from traditional coral reef management at Ahus Island, Papua New Guinea. [Conservation Biology 19, 1714-1723.](#)

2. In villages in Madang Province in Papua New Guinea and North Sulawesi, Indonesia, fishers periodically close areas to harvesting and then open them for specified periods of time. Areas managed with periodic closures have higher biomass and average body size of target fish species than unmanaged areas, and both long-lived and short-lived species benefit from periodic closures. Fishers are able to harvest fish for important events without depleting the stock in the periodically harvested areas.

Cinner, J., Marnane, M.J., McClanahan, T.R., & Almany, G.R. (2005). Periodic closures as adaptive coral reef management in the Indo-Pacific. [Ecology and Society 11\(1\), 31.](#)

### **Gear/Vessel Restrictions**

In Ahus Island in Papua New Guinea, the community prohibits spear and net fishing in six areas of the reef lagoon, while line fishing is unregulated. A comparison of the reef ecosystem inside and outside of the areas with gear restrictions found that the areas where spear and net fishing were prohibited had 60% more biomass of fish. The individual fish were also larger and there was less discarded gear inside the restricted area. There was no significant difference in the overall fish abundance, species richness of fish, or coral cover and diversity.

Cinner, J.E., Marnane, M.J., & McClanahan, T.R. (2005). *Conservation and community benefits from traditional coral reef management at Ahus Island, Papua New Guinea*. [\*Conservation Biology\* 19, 1714-1723.](#)

### **Deployment Limits**

In a lagoon fishery in Thua Thien Hue Province, Vietnam, fisheries organizations worked to reduce the fishing capacity by decreasing the number of fixed fishing gears present. The amount of fishing gear had previously been increasing without any control over the number and placement of traps and nets. In 2010, the fisheries organizations began a consensus-based process to determine gear reductions of traps and bottom nets in the lagoon.

Takahashi, B. & van Duijn, A. P. (2012). *Operationalizing fisheries co-management: Lessons learned from lagoon fisheries co-management in Thua Thien Hue Province, Viet Nam*. FAO Regional Office for Asia and the Pacific, Bangkok. [RAP Publication 2012/02. 131 pp.](#)

### **Sex-specific Controls**

The fisheries cooperatives in Baja California, Mexico have been successful at managing their resources sustainably, with increased landings of spiny lobster over the past forty years. Among other regulations, the cooperatives prohibit the capture of egg-bearing females, which contributes to the sustainability of the fishery.

Orensanz, J.M., & Seijo, J.C. (2013). *Rights-based management in Latin American fisheries*. [FAO Fisheries and Aquaculture Technical Paper 582, Rome. pp. 136.](#)

### **Seasonal Closures**

In 1990, the U.S. Virgin Islands Division of Fish and Wildlife and the Caribbean Fisheries Management Council instituted a seasonal closure of a red hind (*Epinephelus guttatus*) spawning aggregation south of St. Thomas, in response to declines in red hind abundance. A subsequent study in 1997 found increases in average length and abundance, as well as normalization of the sex ratio compared to before the creation of the seasonal closure.

Beets, J., & Friedlander, A. (1998). *Evaluation of a conservation strategy: a spawning aggregation closure for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands*. [Environmental Biology of Fishes 55, 91-98.](#)

### **Protection of Ecologically Important Species**

In 2010, the government of Bonaire prohibited the harvest of parrotfish with the goal of protecting species that help maintain coral reef health. Parrotfish biomass declined from

2003-2011, but the rate of decline slowed after 2011. From 2011-2013, the density of parrotfish increased, likely in response to the fishing ban.

*Stamieszkin, K., & Arnold, S.N. (2013). Trends in Bonaire's herbivorous fish: change over time, management effects and spatial patterns. In: [Status and Trends of Bonaire's Reefs in 2013: Causes for Optimism](#), eds. Steneck, R.S., Arnold, S.N., & Rasher, D.B. University of Maine School of Marine Sciences. Pp. 17-31*