

# Fisheries Management Assessment Guidance

## FMA

### FMA Toolkit Overview

#### Purpose Statement

This toolkit provides the tools to assess small-scale fisheries and achieve fishery goals by adaptive management. The toolkit will help you implement fisheries management measures based on the best available science, assess how these management interventions are performing, and then adjust them as necessary. This toolkit will help you create an Adaptive Fisheries Management Plan

#### Suggested Audience

This toolkit 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 toolkit requires general knowledge in fisheries ecology, fisheries management, population dynamics, local and regional fishery management controls. Familiarity working with fisheries data is desired. Importantly, facilitation and communication skills are needed to coordinate and lead multi-stakeholder discussions.

#### Toolkit Objectives

The FMA toolkit 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 toolkit guides managers in:

- Assessing and visualizing available fisheries data.
- Determine how data should be used to monitor and evaluate target species overtime.
- Perform data-limited assessment methods to evaluate fisheries performance.
- Determine fisheries management controls (regulations) and harvest control rules to achieve fisheries goals (i.e., limit fishing mortality, reduce bycatch, increase size, etc.)
- Design an Adaptive Fisheries Management Plan that defines a process to review management and adapt periodically over time using the best available scientific data and local ecological knowledge.

## **When to Use the Toolkit**

The FMA toolkit should be used on an annual basis (at least for the first few years) to use as an adaptive management tool. As time progresses and more data and information become available for the fishery, different assessment methods and management tiers may be used 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 toolkit**

The FMA toolkit needs a minimum amount of data to be used. The most important data for data-limited fisheries assessment come from catch reporting, boat intercept or landing site surveys, fishery-dependent length composition surveys, and fishery-independent surveys (using underwater visual surveys or experimental fishing). Below is the minimum data requirements and additional recommended data.

### **Minimum required data**

- Qualitative characterization of the fishery (including local history, gear types, target species, fishing locations, fishing seasons, etc.)
- Managed access and reserve size and location (if applicable)
- List or prioritized species and goals for management
- Estimated vulnerability of prioritized target species

### **Additional recommended data**

- Landings, effort, and CPUE of key target species
- Length composition data of 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
- Information on violations of managed access and reserve regulations
- Qualitative information on the community's preparedness for implementing fisheries management and what barriers that may need to first be removed

## Supporting Documents

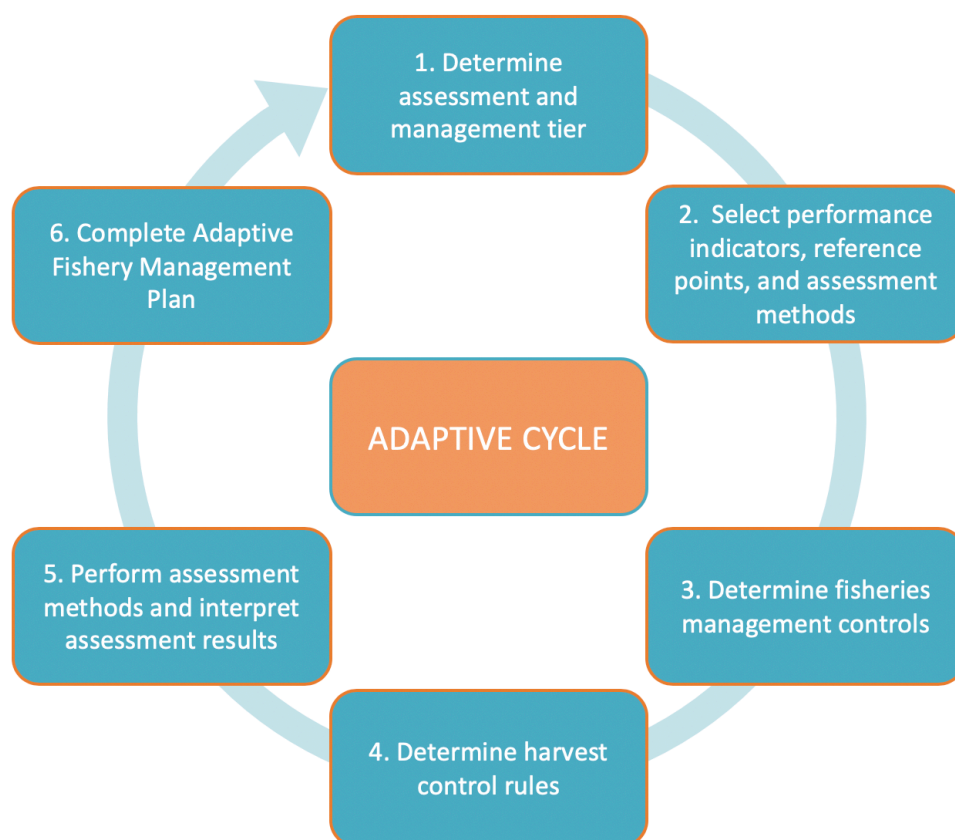
The FMA Toolkit Dashboard provides practitioners with a streamlined way of performing the methods. There are also accompanying Excel workbooks for each assessment method included in the FMA Toolkit that can be used as training tools for teaching assessment methods.

## How this toolkit was developed

This toolkit builds on extensive research over the past decades in data-limited fisheries assessment and management approaches. This toolkit also uses 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, Belize Science Team, and several members of the Fish Forever team ([McDonald et al., 2017](#), [Harford et al., 2016](#)).

## Adaptive Fisheries Assessment Management Framework

This toolkit will guide you through a **six-step** process that should be conducted on an annual basis (Fig. 1). The FMA Toolkit Dashboard guides you through each step in performing the data-limited assessments.



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



## **Step 1 – Determine Assessment Tier, Management Category, and Visualize Data**

The assessment and management tier are based on the data you have available and will determine what assessment and management options you have at your disposal.

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

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.

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.

## **Step 3 – Determine Appropriate Fisheries Management Controls**

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

## **Step 4 – Define Harvest Control Rules**

Harvest control rules help stakeholders to compare performance indicators with reference points and adjust fisheries management controls accordingly. That is, a harvest control rule is a plan for management actions. For example, a simple harvest control rule could specify that if fishing mortality is above natural mortality, the total allowable catch should be reduced. You will use the harvest control rules and the interpretation of assessment results to adjust fisheries management controls appropriately.

## **Step 5 – Perform Assessment Methods and Interpret Assessment Results**

Use several assessment methods to calculate the selected performance indicators and reference points. This section will guide you in using each assessment method through the toolkit dashboard.

Interpret the assessment results together with local ecological knowledge and other available data to determine appropriate fisheries management controls and harvest control rules.

## **Step 6 – Complete Adaptive Fishery Management Plan**

Use the outputs of the FMA toolkit to fill out a Fishery Management Plan template for a fishery. The template can be adapted to specific fisheries and regions.

# FMA Toolkit Dashboard

## Step 1 – Determine Assessment Tier and Management Category

*What information do I have, and how can I use it?*

Determine the assessment and management “tier” of the fishery based on the information and amount of data available (Table 1). Depending on the available data and the time the data have been collected, you will have different options for fisheries management controls and assessment methods (Tier 1 to 3). The tier you determine during this step will be used throughout the remaining steps of the toolkit.

Table 1. FMA Toolkit assessment methods and management tiers.

Assessment tier	Management category	Amount of data required
Tier 1	Precautionary assessment and management	New sites < 1 year of underwater visual survey data, catch/effort data, and length-composition data
Tier 2	Preliminary adaptive assessment and management	About 1 year of catch/effort data and length-composition data
Tier 3	Multi-indicator framework for adaptive assessment and management	One or more years of catch/effort data and length-composition data.

### Step 1a – Fill out your data Inventory and select species

Fill out your inventory of available data following the templates in the dashboard.

### Step 1b – Determine assessment and management tier

Determine what assessment tier (1-3) 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 tier to the next to assess your fishery. The three assessment tiers and management categories are described below.

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

Tier 1 describes a new site with no pre-existing standardized data collection (in most scenarios). 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 (FMCs) 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.

***Tier 2 - Preliminary Adaptive Assessment and Management (~1 year of data)***

Tier 2 sites may have roughly one year of data that come from a combination of catch reporting, boat intercept or landing site survey, or fishery-dependent length-composition surveys. This tier provides a preliminary assessment and management methods for a fishery. Several FMCs can be used in combination to meet multiple management objectives.

***Tier 3 – Multi-Indicator framework for Adaptive Assessment and Management (>1 years of data)***

Tier 3 sites may have time series data (>1 year) that can be used to examine trends in multiple performance indicators and develop more informed FMCs. Within Tier 3, target species may have multiple performance indicators based on different data streams (e.g., catch records, biomass, 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. Additionally, with time series data, limits and targets can be estimated from running averages or the average of the past few years that account for variability in the environment and the fishery. Lastly, ecosystem-level indicators should be included if the sustainable provision of non-fishery ecosystem services is a management goal.

**Step 1c – Visualize available data**

Explore the available data by plotting length composition data, landings and effort data or underwater visual survey data of selected species for analysis.

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

*What is the best way to determine the status of the fishery?*

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 is a goal, fished/unfished density ratio may be used as a performance indicator and a high fished/unfished density ratio as the target reference point.

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

Select appropriate performance indicators for your fishery using **Table 2.1** as guidance, and assess the pros, cons, and the types of species each indicator is appropriate for. Performance indicators will depend on the assessment tier the fishery falls under. Whenever possible, choose 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 tier selected.

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

For Tier 1, managers can perform a basic qualitative fisheries assessment using local ecological knowledge about the fishery, such as types of fishing gear that are currently used, changes in the fishing seasons that have been observed over time, and changes in species composition of landings over time. See **Table 2.1** for performance indicators for Tier 1.

At a minimum, we recommended using these performance indicators for Tier 1:

- At least one indicator based on qualitative fisheries characterization
- At least one fishery-independent indicator based on underwater visual survey or experimental fishing (if available)

### ***Tier 2 – Preliminary Adaptive Assessment and Management (~ 1 year of data)***

Performance indicators in Tier 2 included those under Tier 1, as well as at least one year of fishery-dependent data that may come from a combination of catch reporting, boat-intercept surveys, and fishery dependent length-composition surveys. See **Table 2.1** for potential performance indicators for Tier 2.

At a minimum, we recommended using these performance indicators for Tier 2:

- All indicators from Tier 1
- At least one indicator based on fishery-dependent length-composition survey

### ***Tier 3 – Multi-Indicator framework for Adaptive Assessment and Management (>1 year of data)***

Tier 3 sites will have a time series of data to examine trends in multiple performance indicators in addition to information and data described under Tiers 1 and 2. See **Table 2.1** for potential performance indicators and the types of species each indicator is appropriate for Tier 3.

At a minimum, we recommended using these performance indicators for Tier 3:

- All indicators from Tier 2
- At least one trend-based indicator that uses a time series of landings or CPUE data

**Table 2.1** Pros and cons of performance indicators

Tier	Performance Indicator	Pros	Cons
1	<b>DESTRUCTIVE FISHING GEAR</b>	Relatively easy metric to monitor using local ecological knowledge	None
1	<b>FISHING SEASON</b>	Relatively easy metric to monitor using local ecological knowledge	Changes in fishing season do not always indicate poor fisheries performance; this may also result from changing environmental or market conditions
1	<b>SPECIES COMPOSITION</b>	Relatively easy metric to monitor using local ecological knowledge	Changes in target species composition do not always indicate poor fisheries performance; this may also result from changing environmental or market conditions
1	<b>SPECIES VULNERABILITY</b>	Easy to interpret a species' relative vulnerability to overfishing relative to other species in the area/ecosystem. This relative vulnerability score can be used to prioritize species for management	It is not an estimate of stock status
1	<b>FISHED: UNFISHED DENSITY RATIO</b> (for key target species)	A relative quick and cheap way to assess the status of target species.	Assumes that a fully-functioning and well-enforced NTZ has been sited appropriately with representative habitat, not useful for highly mobile targets.
1	<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 EBFM goals.	Assumes that a fully-functioning and well-enforced NTZ has been sited appropriately with representative habitat, not useful for highly mobile targets. Assumes NTZ are

			representative of historical, unfished biomass.
2.3	<b>AVERAGE LENGTH</b>	Easy, cheap metric to assess changes in the status of a fishery	It does not capture selectivity of the fishery, or is fishing is prosecuted in nursery grounds
2.3	<b>FISHING MORTALITY</b>	Mortality rates are critical for determining abundance of fish populations	All of the models assume equilibrium conditions. Most of these methods only reflect fish that have recruited to a fishery and does not reflect the full age structure of a stock.
2,3	<b>SPAWNING POTENTIAL RATIO (SPR)</b>	It can be used with fishery independent and dependent data	Assumes equilibrium conditions and an index based on the early life history of a fish, it must be remembered that many things can happen to the fish before they are large enough to harvest.
2,3	<b>AVERAGE LENGTH</b>	Easy, cheap metric to assess changes in the status of a fishery when stratified across sampling unit (gear, efforts, fishing zone)	With little to no historical information on the length of the catch or with no information on gear selectivity, the average length could bias the expected potential size distribution.
2,3	<b>FROESE INDICATORS</b>	Proved estimate of the status of the stock, in comparison to sustainability reference points	does not contribute to biomass sustainability reference points
3	<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 abundance history and an entire geographic range. Can be skewed, depending on sampling regime. May have species-specific biases
3	<b>TOTAL LANDINGS</b>	When sampling is stratified, can provide an estimate of abundance	Seldom proportional to abundance history and an entire geographic range, because of fishing location biases and lack of sampling stratification

## Step 2b – Select reference points

Select reference points for each of your chosen performance indicators. **Table 2.2** offers guidance on selection of generic reference points for each performance indicator. This information come from the literature or historic data. Consult scientists for advice for appropriate reference points is needed.

For each performance indicator, select a **target reference point** (TRP) and a **limit reference point** (LRP). A 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. Management is often aimed to achieve or maintain this target. A LRP is a numerical value that indicates that the fishery's performance is unacceptable (e.g., overfished). At LRP, management action is required to improve the fishery or restore populations.

To select reference points chose:

- Length-based indicators and fishery-independent-based indicators from the scientific literature using comparable species and geographic locations.
- CPUE and landing-based indicators from a time series data based on trends or running averages.

The dashboard will guide you through this selection process with a series of question that will help ensure that assumptions associated with each performance indicators are met.

## Step 2c – Select assessment methods

Select the appropriate assessment method for each performance indicator chosen using **Table 2.2** as a guidance. Most performance indicators have only one associated assessment method, although the performance indicator of fishing mortality can be assessed in different ways. For detailed description of each assessment method see below.

**Table 2.2.** Selecting performance indicators, reference points, and assessment methods.

Data Stream (Tier)	Performance Indicator	Target Reference Point	Limit Reference Point	Assessment Methods	Target Species
Qualitative survey  (Tier 1)	<b>DESTRUCTIVE FISHING GEAR</b>	No destructive fishing practices being used	Destructive fishing practices being used	Qualitative assessment of MA-Reserve	All fish and invertebrates
	<b>FISHING SEASON</b>	No changes in the fishing season	Increased variability in fishing season, or decreased fishing season	Qualitative assessment of MA-Reserve	All fish and invertebrates
	<b>TARGET 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.	Qualitative assessment of MA-Reserve	All fish and invertebrates
Productivity and Susceptibility Analysis (PSA)  (Tier 1)	<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	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	Productivity and susceptibility analysis	All fish and invertebrates species present in the ecosystem

Data Stream (Tier)	Performance Indicator	Target Reference Point	Limit Reference Point	Assessment Methods	Target Species
		higher vulnerability estimates (>2.0 PSA score)			
Underwater visual surveys or experimental fishing  (Tier 1)	<b>FISHED/UNFISHED DENSITY RATIO</b> (for key target species)	Fished/unfished density ratio > 0.6	Fished/unfished density ratio < 0.4	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)	Fished/unfished biomass ratio $\geq 0.5$	Fished/unfished biomass ratio $\leq 0.25$	Coral reef thresholds	Multi-species finfish fisheries
	<b>AVERAGE LENGTH</b>	Decrease in the size of unfished individuals outside of the NTZ, in comparison to previous years	Rapid decrease in the size of individuals outside of the NTZ, in comparison to previous years	Average length	Multi-species, habitat associated targets (not a good indicator for highly mobile species)

Data Stream (Tier)	Performance Indicator	Target Reference Point	Limit Reference Point	Assessment Methods	Target Species
Fishery dependent length-composition survey <b>(Tier 2 &amp; 3)</b>	<b>FISHING MORTALITY/ NATURAL MORTALITY RATIO (F/M)</b>	$F/M < 1$ (F is fishing mortality, M is natural mortality)	$F = 2M$	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.
	<b>SPAWNING POTENTIAL RATIO (SPR)</b>  *M is natural mortality, k is von Bertalanffy growth rate)	Slow growing species, $M/k < 1$ (grouper) $SPR \geq 40\%$  Fast growing species, $M/k > 1$ (lobster) $SPR < 20\%$	Slow growing species, $M/k < 1$ (grouper) $SPR < 40\%$  Fast growing species, $M/k > 1$ (lobster) $SPR < 20\%$	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>	Increase in average length	Decrease in average length or mature adults	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.

Data Stream (Tier)	Performance Indicator	Target Reference Point	Limit Reference Point	Assessment Methods	Target Species
Fishery dependent length-composition survey  (Tier 2 & 3)	<b>FROESE INDICATORS</b>	100% of catch – optimal  < 10% of the catch are <i>mega-spawners</i>  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	Froese sustainability indicators	All fish and invertebrate target with known length-age/maturity relationships
Catch reporting system & boat intercept/landing site survey  (Tier 3)	<b>CPUE</b>	Stable CPUE	Rapidly decreasing CPUE, in comparison to previous year or to running average	Catch trends	All targets that do not have high selectivity of habitat stratification.
	<b>TOTAL LANDINGS</b>	Increase in total landing	Rapidly decreasing total landings, in comparison to previous year or to running average	Catch trends	All targets that do not have high selectivity of habitat stratification.

## Assessment Methods Descriptions

### *Fishery Independent Data*

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

**Description:** This method uses the ratio of total fish biomass inside a 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 less 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 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, 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
- $L_c$ , 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

## Step 3 – Determine Appropriate Fisheries Management Controls

*What fisheries management controls are appropriate for your fishery?*

### Step 3a – 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 **Step 3b**.

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 3.1-3.3** 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 **Step 3c**. Alternatively, if the FMCs are not performing as your community may wish or no FMCs exist, proceed to **Step 3b** to select different or new FMCs.

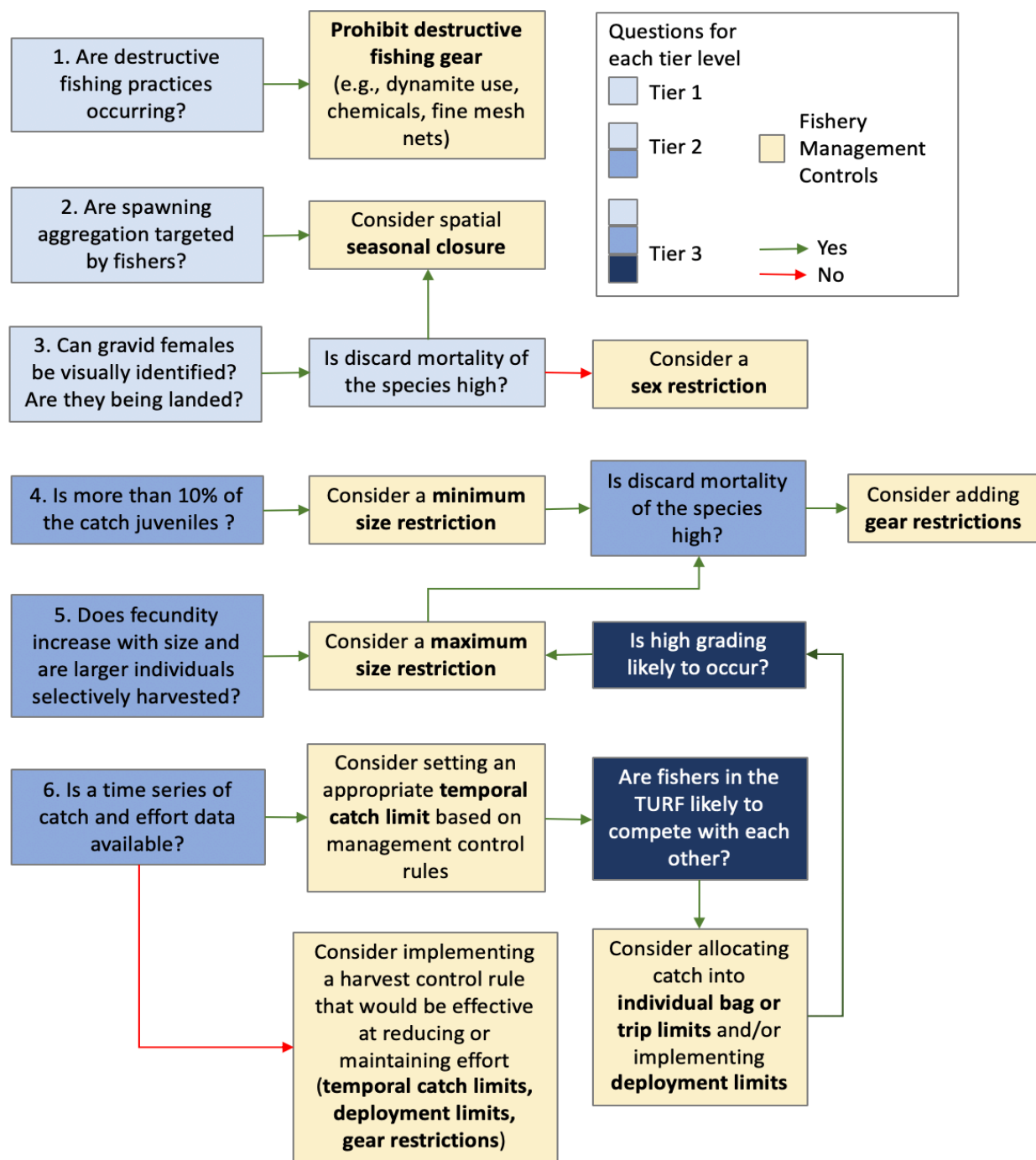
Quantitatively assess how well existing FMCs are doing in terms of fisheries performance indicators (**Step 2**) by performing data-limited assessments using any available data. Based on this quantitative evaluation, you may wish to change FMCs during the next iteration of the FMA cycle.

### Step 3b – 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., catch limits). 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 **Appendix 1**). 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 2**) 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 2.** Decision tree to help identify appropriate Fisheries Management Controls.

**Table 3.1** Descriptions and implementation considerations for different fisheries management controls

Fishery Management Control	Primary Objective	Minimum data requirement	Enforcement
<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.

### **Step 3c – 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 3.1-3.3**, 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 3.1-3.3**. 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 3.2-3.3** 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 3.2-3.3**) by considering the “ease of implementation” for each FMC listed in **Step 3a** and how it aligns with the specific conditions and characteristics the site.

### **Step 3d – 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.

### **Step 3e – 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 3.2** 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	Can be implemented to protect age-structure by modifying selectivity	May protect vulnerable life history stages	Do not directly protect habitat but can be designed to reduce the impact a	May reduce bycatch by improving selectivity in a fishery

	control total harvest of a stock	to allow individuals of a specific size to escape harvest.		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 Important Species</b>	Protects the SSB of the species of interest but does not directly protect SSB	Protects the age-structure of the protected population but does not directly protect	Does not directly protect vulnerable life history stages	May protect the habitat if the species of interest plays an important role in	Can increase discards because individuals of the protected species can be discarded to

	of other target species	age-structure of other target species		maintaining ecosystem health	avoid enforcement penalties.
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**Table 3.3** Effectiveness of different fisheries management controls in meeting socio-economic objectives

Fisheries Management Control	Increase Fisher Profits	Increase Product Quality	**Maintain Fishing Efficiency	Fisher Safety
<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 have a negative impact on the safety of fishing because during the race-to-fish, fishers may continue fishing even if fishing conditions become unsafe. Individual allocation of catch limits can have a positive impact on fisher safety since they can eliminate the race-to-fish.
<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	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 have a negative impact on safety if increasing the number of fishing trips means that they will need to fish in bad weather

Fisheries Management Control	Increase Fisher Profits	Increase Product Quality	**Maintain Fishing Efficiency	Fisher Safety
	recovers, there may be a long-term increase in fisher profits.			
<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 be discarded. Once a depleted stock recovers, there may be a long-term increase in fisher profits.	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 a long-term increase in fishing efficiency.	Do not have a direct impact on the fisher safety
<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 have a negative impact on the safety of fishing because during the race-to-fish, fishers continue fishing even if fishing conditions become unsafe
<b>Gear Restrictions – Gear Type</b>	Incentivize fishers to invest and improve in unregulated dimensions of gear, increasing fishing costs and reducing short-term	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	Do not typically have a direct impact on fisher safety (unless banning destructive fishing gear that can have

Fisheries Management Control	Increase Fisher Profits	Increase Product Quality	**Maintain Fishing Efficiency	Fisher Safety
	fisher profits. Once a depleted stock recovers, there may be a long-term increase in fisher profits.		a long-term increase in fishing efficiency.	unintended negative impacts on fisher, such as dynamite).
<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 not have a direct impact on fisher safety
<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 not have a direct impact on fisher safety
<b>Seasonal Closures</b> to Protect Vulnerable Life History Stages	Do not increase short-term fisher profits and may cause a decrease in income because fishers often shift to less valuable species. Once a depleted stock recovers, there may be a long-term increase in fisher profits.	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 an additional long-term increase in fishing efficiency.	May have a negative impact on fisher safety because during the race-to-fish, fishers may fish in unsafe conditions

Fisheries Management Control	Increase Fisher Profits	Increase Product Quality	**Maintain Fishing Efficiency	Fisher Safety
<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.	Does not have an impact on fisher safety

## Step 4 – Define Harvest Control Rules

*How should FMCs be adjusted according to the performance indicators of the fishery?*

*Harvest Control Rules (HCRs)* will be used to adjust FMCs 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. Note that HCRs should be based on realistic compliance and enforcement concerns and address community goals for your 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 4a – Define general harvest control rules for all possible interpretations

Define general harvest control rules for all possible interpretations (i.e., combination of performance indicators). In the next step, you will add specificity to your harvest control rules (e.g., if the performance indicator is 20% below the target reference point, reduce the total allowable catch (TAC) by 20%). 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.

Use **Table 4.1** as framework for defining general HCRs. This table contains the performance indicators that are associated with each tier and suggests HCRs from the literature. For each performance indicator and assessment result, the table lists a number of potential interpretations and corresponding HCRs. The table provides some examples and it is illustrative only.

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 (see **Table 4.2** for examples).

#### **Step 4b – Add specificity to harvest control rules**

Add specificity to your HCRs (e.g., if the performance indicator is 20% below the target reference point, reduce the total allowable catch by 20%). 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. Productivity of key target species is an output of the FLAGS toolkit. This information may either come from a PSA result or a more data-limited qualitative approach for assessing species productivity.
  - 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**
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, 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 social survey data when setting HCRs. KAP 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 any NTZ when setting HCRs. Sites with a small NTZ relative to the size of the fishery may wish to set more restrictive HCRs (i.e., if indicators are interpreted to mean poor fisheries performance, make more drastic adjustments to the FMCs). Sites with an NTZ that is not placed explicitly in areas that protect critical habitat may also wish to set stricter HCRs. Sites with larger NTZs that protect a significant portion of critical habitat could be more lenient in their HCRs. Often, large and well-placed NTZs 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	Mgmt. Response	Harvest Control Rule Suggested
<b>Fishing Gear (Tier 1)</b>	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	●	1. Ban destructive fishing practices
	No destructive fishing practices being used	Non-destructive fishing practices are able to efficiently catch fish and/or destructive fishing practices have been banned	●	1. If there is no reason to believe precautionary management is necessary, make no changes to fisheries management controls <b>or</b> 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)
<b>Fishing Season (Tier 1)</b>	Increased variability in fishing season, or decreased fishing season	Ecosystem likely not healthy enough to support historical fishing season	●	1. Make fisheries management controls more restrictive (i.e., <b>increase TAC, increase effort cap</b> , add or modify certain controls, expand NTZ, etc.)

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
	No changes in the fishing season	Ecosystem may be healthy enough to support historical fishing season	●	<ol style="list-style-type: none"> <li>1. If there is no reason to believe precautionary management is necessary, make no changes to fisheries management controls <b>or</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)</li> </ol>
<b>Target Species Composition</b>  (Tier 1)	Change in composition of caught species (fewer species, more pelagic)	Ecosystem likely not healthy enough to support historical target species	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>
	No change in composition of caught species	Ecosystem may be healthy enough to support historical target species	●	<ol style="list-style-type: none"> <li>1. If there is no reason to believe precautionary management is necessary, make no changes to fisheries management controls <b>or</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)</li> </ol>
<b>Species Vulnerability</b>	Target species have high vulnerability	Target species have high susceptibility and/or low productivity	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
<b>(Tier 1)</b>	Target species have medium vulnerability	Target species have medium susceptibility medium productivity	●	1. Make fisheries management controls more restrictive (i.e., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.)
	Target species have low vulnerability	Target species have low susceptibility and/or high productivity	●	1. If there is no reason to believe precautionary management is necessary, make no changes to fisheries management controls <b>or</b> 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)
<b>Fished/unfished density ratio</b> (for key target species)  <b>(Tier 1)</b>	Indicator >= Target	Fishing pressure appropriate for maintaining or improving the health of the ecosystem	●	1. Make no changes to fisheries management controls <b>or</b> 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)
		Unfished area has a low density and does not represent a healthy undisturbed area (significant illegal fishing is occurring within the NTZ)	●	1. Consider improved enforcement of NTZ <b>and</b> 2. Consider targeted social marketing to improve compliance with NTZ <b>and</b> 3. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC,

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
				decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low density and does not represent a healthy undisturbed area (NTZ is new and has not yet led to substantial improvements in ecosystem health)	●	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low density and does not represent a healthy undisturbed area (NTZ is small with large amounts of species movement between fished and unfished areas)	●	1. Consider expansion or relocation of NTZ <b>and</b> 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	Target > Indicator > Limit	High fishing pressure putting ecosystem at risk for impending state change	●	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Environmental stochasticity putting ecosystem at risk for impending state change	●	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		Unfished area has a low density and does not represent a healthy undisturbed area (significant illegal fishing is occurring within the NTZ)	●	<ol style="list-style-type: none"> <li>1. Consider improved enforcement of NTZ <b>and</b></li> <li>2. Consider targeted social marketing to improve compliance with NTZ <b>and</b></li> <li>3. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Unfished area has a low density and does not represent a healthy undisturbed area (NTZ is new and has not yet led to substantial improvements in ecosystem health)	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Unfished area has a low density and does not represent a healthy undisturbed area (NTZ is small with large amounts of species movement between fished and unfished areas)	●	<ol style="list-style-type: none"> <li>1. Consider expansion or relocation of NTZ <b>and</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
	Limit >= Indicator	High fishing pressure has caused an ecosystem state change; fishery in danger of collapse	●	<ol style="list-style-type: none"> <li>1. Close fishery <b>and</b></li> <li>2. Implement fishery recovery plan</li> </ol>
		Extreme environmental stochasticity has caused an	●	<ol style="list-style-type: none"> <li>1. Close fishery <b>and</b></li> <li>2. Implement fishery recovery plan</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		ecosystem state change; fishery in danger of collapse		
<b>Coral Reef Thresholds (aggregated across species)</b>  <b>(Tier 1)</b>	Unfished biomass Indicator $\geq$ Target  <b>And</b>  Fished/Unfished biomass ratio $\geq$ Target	Fishing pressure appropriate for maintaining or improving the health of the ecosystem	●	1. Make no changes to fisheries management controls <b>or</b> 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)
		Unfished area has a low biomass and does not represent a healthy undisturbed area (significant illegal fishing is occurring within the NTZ)	●	1. Consider improved enforcement of NTZ <b>and</b> 2. Consider targeted social marketing to improve compliance with NTZ <b>and</b> 3. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Unfished area has a low biomass and does not represent a healthy undisturbed area (NTZ is new and has not yet led to substantial improvements in ecosystem health)	●	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		Unfished area has a low biomass and does not represent a healthy virgin area (NTZ is small with large amounts of species movement between fished and unfished areas)	●	<ol style="list-style-type: none"> <li>1. Consider expansion or relocation of NTZ <b>and</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Unfished area does not have comparable habitat to fished area (unfished area habitat not as healthy as fished area)	●	<ol style="list-style-type: none"> <li>1. Consider expansion or relocation of NTZ <b>and</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
	Limit ≤ Unfished biomass Indicator ≤ Target  <b>And</b>	High fishing pressure putting ecosystem at risk for impending state change	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>
		Environmental stochasticity putting ecosystem at risk for impending state change	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
	Limit <= Fished/Unfished biomass ratio <= Target	Unfished area has a low density and does not represent a healthy virgin area (significant illegal fishing is occurring within the NTZ)	●	<ol style="list-style-type: none"> <li>1. Consider improved enforcement of NTZ <b>and</b></li> <li>2. Consider targeted social marketing to improve compliance with NTZ <b>and</b></li> <li>3. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Unfished area has a low density and does not represent a healthy virgin area (NTZ is new and has not yet led to substantial improvements in ecosystem health)	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Unfished area has a low density and does not represent a healthy virgin area (NTZ is small with large amounts of species movement between fished and unfished areas)	●	<ol style="list-style-type: none"> <li>1. Consider expansion or relocation of NTZ <b>and</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Unfished area does not have comparable habitat to fished area (unfished area habitat not as healthy as fished area)	●	<ol style="list-style-type: none"> <li>1. Consider expansion or relocation of NTZ <b>and</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
	Limit $\geq$ Unfished biomass Indicator	High fishing pressure has caused an ecosystem state change; fishery in danger of collapse	●	1. Close fishery <b>and</b> 2. Implement fishery recovery plan
	<b>OR</b> Limit $\geq$ Fished/Unfished biomass ratio	Extreme environmental stochasticity has caused an ecosystem state change; fishery in danger of collapse	●	1. Close fishery <b>and</b> 2. Implement fishery recovery plan
<b>Fishing Mortality (F)</b>  <b>(Tier 2 &amp;3)</b>	Indicator $\geq$ Limit	High fishing pressure negatively affecting size structure and spawning stock biomass; fishery in danger of collapse	●	1. Close fishery <b>and</b> 2. Implement fishery recovery plan
		Extreme environmental stochasticity negatively affecting size structure and spawning stock biomass; fishery in danger of collapse	●	1. Close fishery <b>and</b> 2. Implement fishery recovery plan
	Limit $>$ Indicator $>$ Target	High fishing pressure affecting size structure and spawning stocks biomass	●	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Fishers targeting nursery grounds	●	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		Gear shift towards less selective gear (more small individuals in catch)	●	<ol style="list-style-type: none"> <li>1. Consider implementing a gear restriction on less selective gear <b>and/or</b></li> <li>2. Consider implementing a minimum size limit (if one does not already exist)</li> </ol>
		Strong recruitment pulse (more small individuals entering the catch)	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)</li> </ol>
		Market selectivity for smaller individuals	●	<ol style="list-style-type: none"> <li>1. Consider implementing a minimum size limit (if one does not already exist)</li> </ol>
		Emigration of large individuals from fishing area	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls</li> </ol>
		Environmental stochasticity affecting size structure and spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
	Target >= Indicator	Fishing pressure appropriate for maintaining or improving size structure of population	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
				believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)
		Gear shift towards more selective gear (fewer small individuals in catch)	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)</li> </ol>
		Market selectivity for larger individuals	●	<ol style="list-style-type: none"> <li>1. Consider implementing a maximum size limit (if one does not already exist)</li> </ol>
		Weak recruitment pulse (fewer small individuals entering the catch)	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Immigration of large individuals to fishing area	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls</li> </ol>
<b>Average Length</b>	Indicator <= Limit	High fishing pressure negatively affecting size structure and	●	<ol style="list-style-type: none"> <li>1. Close fishery <b>and</b></li> <li>2. Implement fishery recovery plan</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
(Tier 2 & 3)		spawning stock biomass; fishery in danger of collapse		
		Extreme environmental stochasticity negatively affecting size structure and spawning stock biomass; fishery in danger of collapse	●	<ol style="list-style-type: none"> <li>1. Close fishery <b>and</b></li> <li>2. Implement fishery recovery plan</li> </ol>
	Limit < Indicator < Target	High fishing pressure affecting size structure and spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>
		Fishers targeting nursery grounds	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>
		Gear shift towards less selective gear (more small individuals in catch)	●	<ol style="list-style-type: none"> <li>1. Consider implementing a gear restriction on less selective gear <b>and/or</b></li> <li>2. Consider implementing a minimum size limit (if one does not already exist)</li> </ol>
		Strong recruitment pulse (more small individuals entering the catch)	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
				TAC, increase allowable effort, remove or modify certain controls, etc.)
		Market selectivity for smaller individuals	●	<ol style="list-style-type: none"> <li>1. Consider implementing a minimum size limit (if one does not already exist) <b>or</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Emigration of large individuals from fishing area	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls</li> </ol>
		Environmental stochasticity affecting size structure and spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
	Target <= Indicator	Fishing pressure appropriate for maintaining or improving size structure of population	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		Gear shift towards more selective gear (fewer small individuals in catch)	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)</li> </ol>
		Market selectivity for larger individuals	●	<ol style="list-style-type: none"> <li>1. Consider implementing a maximum size limit (if one does not already exist) <b>or</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Weak recruitment pulse (fewer small individuals entering the catch)	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Immigration of large individuals to fishing area	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls</li> </ol>
<b>Spawning Potential Ratio</b>	Indicator <= Limit	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	●	<ol style="list-style-type: none"> <li>1. Close fishery <b>and</b></li> <li>2. Implement fishery recovery plan</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
<b>(Tier 2 &amp; 3)</b>		Extreme environmental stochasticity affecting size structure and spawning stock biomass; fishery in danger of collapse	●	<ol style="list-style-type: none"> <li>1. Close fishery <b>and</b></li> <li>2. Implement fishery recovery plan</li> </ol>
	Limit > Indicator < Target	High fishing pressure affecting size structure and spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>
		Fishers targeting nursery grounds	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>
		Gear shift towards less selective gear (more small individuals in catch)	●	<ol style="list-style-type: none"> <li>1. Consider implementing a gear restriction on less selective gear <b>and/or</b></li> <li>2. Consider implementing a minimum size limit (if one does not already exist)</li> </ol>
		Strong recruitment pulse (more small individuals entering the catch)	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)</li> </ol>
		Market selectivity for smaller individuals	●	<ol style="list-style-type: none"> <li>1. Consider implementing a minimum size limit (if one does not already exist) <b>or</b></li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
				2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Emigration of large individuals from fishing area	●	1. Make no changes to fisheries management controls
		Environmental stochasticity affecting size structure and spawning stock biomass	●	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	Target <= Indicator	Fishing pressure appropriate for maintaining or improving size structure of population and spawning stock biomass	●	1. Make no changes to fisheries management controls <b>or</b> 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)
		Gear shift towards more selective gear (fewer small individuals in catch)	●	1. Make no changes to fisheries management controls <b>or</b> 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		Market selectivity for larger individuals	●	<ol style="list-style-type: none"> <li>1. Consider implementing a maximum size limit (if one does not already exist) <b>or</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Weak recruitment pulse (fewer small individuals entering the catch)	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		Immigration of large individuals to fishing area	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> </ol>
<b>Froese Indicators (Tier 2 &amp; 3)</b>	All Indicators at or better than Target (Lopt=100%, Lmat>90%, Lmega<10%)	Fishing pressure appropriate for maintaining or improving size structure of population and spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase effort cap, etc.)</li> </ol>
		Gear shift towards more or less selective gear	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		Change in recruitment	●	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Change in spatial distribution of stock	●	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	Target > Lopt > Limit	Market selectivity for smaller individuals	●	1. Consider implementing a minimum size limit (if one does not already exist) <b>or</b> 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
	<b>And/or</b> Target > Lmat > Limit	High fishing pressure affecting size structure and spawning stock biomass	●	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)
		Fishers targeting nursery grounds	●	1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		Strong recruitment pulse (more small individuals entering the catch)	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)</li> </ol>
		Emigration of large individuals from fishing area	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls</li> </ol>
		Environmental stochasticity affecting size structure and spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)</li> </ol>
	Limit > L <sub>mega</sub> > Target	Market selectivity for larger individuals	●	<ol style="list-style-type: none"> <li>1. Consider implementing a maximum size limit (if one does not already exist) <b>or</b></li> <li>2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
		High fishing pressure affecting size structure and spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		Weak recruitment pulse (fewer small individuals entering the catch)	●	1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)
		Immigration of large individuals to fishing area	●	1. Make no changes to fisheries management controls <b>or</b>
	Lopt < Limit (Lopt<80%)	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	●	1. Close fishery <b>and</b> 2. Implement fishery recovery plan
	Lmat < Limit (Lmat<50%)	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	●	1. Close fishery <b>and</b> 2. Implement fishery recovery plan
	Lmega > Limit (Lmega >20%)	High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse	●	1. Close fishery <b>and</b> 2. Implement fishery recovery plan
<b>CPUE (Tier 3)</b>	Indicator >= Target	Fishing pressure appropriate for maintaining or improving spawning stock biomass	●	1. Make no changes to fisheries management controls <b>or</b> 2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
				TAC, increase allowable effort, remove or modify certain controls, etc.)
		Change to more efficient gear type	●	<ol style="list-style-type: none"> <li>1. Consider implementing a gear restriction on less selective gear <b>and/or</b></li> <li>2. Consider implementing a minimum size limit (if one does not already exist)</li> </ol>
		Serial depletion (fishers have moved from depleted fishing grounds to less depleted fishing grounds, such as offshore areas)	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>
		Misreporting of effort; reported effort too low	●	<ol style="list-style-type: none"> <li>1. Modify catch reporting protocols <b>and/or</b></li> <li>2. Perform social marketing dedicated towards increasing catch reporting compliance <b>and</b></li> <li>3. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)</li> </ol>
		Fishing of spawning aggregations / hyperstability	●	<ol style="list-style-type: none"> <li>1. Ban fishing of spawning aggregations</li> </ol>
	Target > Indicator > Limit	Environmental stochasticity negatively affecting spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		Change to less efficient gear type	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)</li> </ol>
		Misreporting of effort; reported effort too high	●	<ol style="list-style-type: none"> <li>1. Modify catch reporting protocols <b>and/or</b></li> <li>2. Perform social marketing dedicated towards increasing catch reporting compliance <b>and</b></li> <li>3. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)</li> </ol>
		High fishing pressure negatively affecting spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>
	Limit >= Indicator	High fishing pressure negatively affecting spawning stock biomass; fishery in danger of collapse	●	<ol style="list-style-type: none"> <li>1. Close fishery <b>and</b></li> <li>2. Implement fishery recovery plan</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
Previous Year's Total Landings  (Tier 3)	Indicator >= Target	Fishing pressure appropriate for maintaining or improving spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)</li> </ol>
		Fishing effort increased last year	●	<ol style="list-style-type: none"> <li>1. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.)</li> </ol>
		Misreporting of landings; reported catch too high	●	<ol style="list-style-type: none"> <li>1. Modify catch reporting protocols <b>and/or</b></li> <li>2. Perform social marketing dedicated towards increasing catch reporting compliance <b>and</b></li> <li>3. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
	Target > Indicator > Limit	High fishing pressure negatively affecting spawning stock biomass	●	<ol style="list-style-type: none"> <li>1. Make fisheries management controls more restrictive (i.e., decrease TAC, decrease effort cap, add or modify certain controls, expand NTZ, etc.)</li> </ol>

Performance Indicator	Assessment Result	Possible Interpretation	Mgmt. Response	Harvest Control Rule Suggested
		Fishing effort decreased last year	●	<ol style="list-style-type: none"> <li>1. Make no changes to fisheries management controls <b>or</b></li> <li>2. If trends have persisted for more than one year and there is no reason to believe precautionary management is necessary, make fisheries management controls less restrictive (i.e., increase TAC, increase allowable effort, remove or modify certain controls, etc.)</li> </ol>
		Misreporting of landings; reported catch too low	●	<ol style="list-style-type: none"> <li>1. Modify catch reporting protocols <b>and/or</b></li> <li>2. Perform social marketing dedicated towards increasing catch reporting compliance <b>and</b></li> <li>3. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.)</li> </ol>
	Limit >= Indicator	High fishing pressure negatively affecting spawning stock biomass; fishery in danger of collapse	●	<ol style="list-style-type: none"> <li>1. Close fishery <b>and</b></li> <li>2. Implement fishery recovery plan</li> </ol>

**Table 4.2.** Example of Harvest Control Rules for three performance indicators

Scenario	Performance Indicators Reference Points			Interpretation / possible causes	Response required	Harvest Control Rules
	<b>MPA Density Ratio <math>\geq 0.50</math></b>	<b><math>F \leq M</math></b>	<b><math>SPR \geq 0.4</math></b>			
<b>1</b>	✓	✓	✓	<ul style="list-style-type: none"> <li>Stock healthy with good productivity, and fishery performance sustainable</li> </ul>	NO	1. Monitor reference point (RP) trends <ol style="list-style-type: none"> <li>Make no change (if RP trends are stable or just above limits)</li> <li>Increase fishing mortality if fished/unfished DR is increasing, F is decreasing, and SPR is increasing</li> </ol>
<b>2</b>	✓	✗	✓	<ul style="list-style-type: none"> <li>Increased pressure or new gear</li> <li>Sampling bias that increases F</li> <li>Large recruitment pulse</li> </ul>	YES	1. Confirm/monitor F values with multiple models/approaches <ol style="list-style-type: none"> <li>No change (if F trends are stable/near limit)</li> <li>Reduce fishing mortality to reduce risk of overfishing</li> </ol>
<b>3</b>	✗	✓	✓	<ul style="list-style-type: none"> <li>Fishing rate sustainable and stock productivity healthy, but stock density at unhealthy levels/ approaching threshold</li> <li>Stock density could be low due to non-fishing factors or historical fishing impacts</li> <li>Error in calculations?</li> </ul>	YES	1. Monitor MPA DR, F and SPR trends and recruitment, gear and behavior patterns <ol style="list-style-type: none"> <li>Make no change if MPA DR stable or increasing and F and SPR trends stable/just above limits.</li> <li>Reduce fishing mortality if MPA DR decreasing, F trend increasing, SPR trend decreasing</li> </ol>

4	X	X	✓	<ul style="list-style-type: none"> <li>○ Potential early warning of growth and recruitment overfishing</li> <li>○ Stock potentially nearing threshold</li> <li>○ Large recruitment pulse</li> </ul>	YES	1. Confirm/monitor SPR values with multiple models/approaches <ol style="list-style-type: none"> <li>a. No change (if SPR trends are stable/near limit)</li> <li>b. Reduce fishing mortality</li> </ol>
5	✓	✓	X	<ul style="list-style-type: none"> <li>○ Abundance levels are healthy, overfishing is not occurring, yet SPR is low</li> <li>○ F or SPR estimate(s) in error?</li> </ul>	YES	1. Confirm/monitor SPR values with multiple models/approaches 2. If SPR continues to be low, consider additional regulatory options to reduce fishing pressure
6	X	✓	X	<ul style="list-style-type: none"> <li>○ Overfishing resulting in reduced abundance and egg production, or</li> <li>○ Error in calculations</li> </ul>	YES	1. Confirm/monitor SPR values with multiple models/approaches 2. Reduce fishing mortality 3. If trend persists consider additional regulatory options to reduce fishing pressure
7	✓	X	X	<ul style="list-style-type: none"> <li>○ Overfishing</li> <li>○ Increased targeting, resulting in high fishing mortality that has not yet manifested as a detectable change in abundance, or</li> <li>○ Error in calculations</li> </ul>	YES	1. Confirm/monitor SPR values with multiple models/approaches 2. Reduce fishing mortality 3. If trend persists consider additional regulatory options to reduce fishing pressure
8	X	X	X	<ul style="list-style-type: none"> <li>○ Overfishing is occurring</li> <li>○ The stock is overfished</li> </ul>	YES	1. Confirm/monitor SPR values with multiple models/approaches 2. Reduce fishing mortality 3. If trend persists, consider additional regulatory options to reduce fishing pressure

## Step 5 - Perform Assessment Methods and Interpret Assessment Results

*What do my assessment methods say about the current status of the fishery?*

### Step 5a – Perform assessment methods

Use your data to calculate the performance indicators by using the chosen assessment methods. Refer to **Step 2c** for detailed descriptions of the assessment methods. Use the FMA toolkit dashboard to run the calculations (see Appendix 2 for instructions on how to install the toolkit)

The FMA toolkit dashboard includes data templates you may fill out using your own data to ensure all data are properly formatted for analysis. Alternatively, the dashboard also specifies the necessary columns for all types of data input. Make sure your data has all necessary column names. Note, all column names must match *exactly* what is specified in the dashboard.

The 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 Philippines. If your species is currently included, you should ensure the life history parameters look reasonable for your particular site. If they are not included, you will need to find these parameters by looking through the literature and using resources such as [FishBase](#).

### Step 5b – Determine possible interpretations for each performance indicator

After the assessment methods are completed, use harvest control rules (**Table 4.1**) to determine the possible interpretation and management implication for each performance indicator following these steps:

- a. Using your assessment results (**Step 5a**) and adequate harvest control rules (**Table 4.1**), select the most likely interpretation from the choices provided in the “Possible Interpretation” column.
- b. Determine the management implication by locating the colored circle traffic light in the “Management Implication column”

### Step 5c – Verify and interpret assessment results

Verify the assessment result using the following steps:

1. Double-check calculations by reviewing the assessment calculations.
2. Double-check that each assessment performed was stratified to the spatial extent of the fishery; for example, run analyses for each gear type, boat type, and/or fishing area.

3. Double-check that reference points are appropriate for your fishery using available literature, expert opinion, and local ecological knowledge
4. Review fishery-dependent and independent sampling protocols; assess whether or not the spatial extent of the fishery-dependent or independent surveys overlap with known or assumed distribution of fish population as well as fishing effort and gear type (only for fishery dependent). If the sampling protocol, fish population, and fishing effort do not overlap, there may be biases in the assessment results that should be considering in your interpretation.
5. Examine any effort metrics to determine if they are consistent with your interpretation
6. Ground-truth assessment result and interpretation with community. Consult with local experts (i.e., fishers, middlemen, 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. Fishers can be especially helpful in interpreting performance indicators that seem counter-intuitive but can be explained by fishermen behavior. For example, if fished/unfished density ratio is down but catch and CPUE are up, the fishermen might say that although fish abundance seems low (low fished/unfished density ratio) prices were high that season and the weather was good, resulting in better targeting (higher CPUE) and higher catches. This process can either take place in a focus group discussion or structured interviews with key stakeholders. Through this process, try to arrive at a consistent interpretation.
7. If trends persist, each performance indicator points towards a consistent interpretation, and if the community agrees with the interpretation, proceed to **Step 5d**
8. In situations where, conflicting indicators cannot be rectified, or if the community cannot corroborate the assessment results, additional community outreach or other forms of social marketing 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 5d**.

### **Step 5d – Adjust Fisheries Management Controls Using Defined Harvest Control Rules**

After interpreting and verifying the assessment results, implement the appropriate HCR defined in **Step 4**. Depending on the severity of the HCR and likely community reaction, it may be necessary to conduct additional community outreach or other social marketing activities to ensure buy-in and compliance. For example, if a limit reference point is reached and the fishery for a particular species must be closed, this will likely require significant community outreach.

## Step 6 – Complete Fishery Management Plan

*How do I take the outputs of the FMA toolkit to create a concrete Fishery Management Plan?*

We have provided a template Fishery Management Plan below. To complete this template, we recommend you use the outputs of the FMA Dashboard and complete a fishery management plan for each species to be managed. Note that the template provided here may need to be adapted to better suit your regional context.

### 6.1 – Fishery Management Plan Template

- **Fishery Overview:**
  - **Location of the Fishery:** Country, state, city, management zone (if applicable).
  - **History:** Provide a brief history of the fishery.
  - **Type(s) of Fishery:** Commercial, recreational, etc. and whether near shore, off shore, or mixed.
  - **Participants:** Number of fishers, number of vessels, number of communities (if applicable), and spatial distribution of participants/ communities.
  - **Fishery Characteristics:** Describe the gear types used in the fishery (e.g., fixed gear, mobile gear, etc.), including numbers for each if possible, as well as the general timeframe (i.e., season) of when the fishery occurs.
  - **Management Characteristics:** Type of method currently used to manage the fishery (e.g., seasons, catch limits, size limits, effort limits, etc.). Also describe the general management decision-making process.
  - **Governance:** Briefly describe key legislation and regulations, as well as types of committees and/or legislative land claims which are part of the decision-making process (based on zones, areas, regions)
  - **Economic, Social, and Cultural Importance of the Fishery:** Provide a brief overview of economic conditions and social, cultural and economic issues.
  - **Species Characteristics:** Provide a brief overview outlining the main biological characteristics of the species with emphasis on the aspects which impact on management of the species. Factors to be covered include range (both globally and locally), populations/stock structure, habitat requirements (including key location where applicable), migration routes and reproductive characteristics (e.g., season, behavior, fecundity, growth rates, spawning grounds).
  - **Ecosystem Interactions:** Briefly describe interactions with other species and the physical environment. Where the information is available briefly describe the effect of climate regime changes on stock status, particularly recruitment and stock productivity.
- **Fisheries Objectives and Challenges:**

*You may use the outputs of the FLAGS toolkit to help complete this section*

- **Management Objectives:** Clearly state long-term objectives for fishery management under the following potential headings:
  - Yield/ Economic
  - Stock Conservation
  - Ecosystem
  - Social and Cultural
  - Compliance
    - For each long-term objective, outline short-term objectives specific for the duration of the plan.
- **List all Trade-Offs Associated with these Objectives:** Briefly explain which objectives conflict with each other, such that one objective may have to be sacrificed to achieve another. Where possible, discuss potential management modifications that may lessen these trade-offs.
- **Current Management Issues:** Provide an overview of current issues in the fishery, including those related to the target species, as well as by-catch and ecosystem concerns. Potential examples of management issues include:
  - **Fisheries Issues** such as conflicts between gear sectors, catch monitoring, by-catch problems and other resource user issues.
  - **Depleted Species Concerns**, including species listed under CITES, and/ or any local endangered/threatened species legislation. Reference existing recovery strategies/management plans where appropriate.
  - **Oceans and Habitat Considerations**, including habitat impacts and discussions of ecologically significant areas that have been identified and documented within the geographic range of the fishery (including marine protected areas (MPAs) or no-take zones. Where information is available on the effect of climate regime change on stock status, it should be considered when developing harvest decision rules and other management measures. Any management measures in place to control aquatic invasive species should also be included.
  - **Gear Impacts**, including losses and resulting impacts.
  - **International Issues**
- **Science and Traditional Knowledge:**

*You may use your Site Level Research Plan, the Global Monitoring & Evaluation Plan, and the Data Collection Manual to help you complete this section.*

- **Available Data:** Provide brief overview of all available data, with references to sources.
- **Data Collection:** Provide a brief overview of the data collection process for the stock(s), including types of data sources utilized (i.e. research vessel trawl surveys,

tagging, index fisheries, CPUE, landing statistics, sentinel fisheries, etc.) and frequency of assessment.

- **Traditional Knowledge:** Provide brief overview of all traditional/ local knowledge.
- **Research:** Provide a brief overview of research projects being conducted during the period of the plan and their purpose. Also include any research needs not currently being addressed. Consider not just the target species, but also research on associated by-catch and habitat.
- **Precautionary Approach (PA):** Where available, provide a brief overview of any PA references established for this resource, including removal references, limit reference points, and upper stock reference points.

- **Adaptive Assessment and Management:**

Provide a brief overview of the **Adaptive Fisheries Assessment and Management Plan**, including data sources, design of data collection and sampling programs, timeline for completion of new/ updated assessments (e.g., yearly), and performance indicators to be evaluated.

- **Step 1: Assessment and management tier chosen.**
  - Data sources:
  - Tier:
- **Step 2: List performance indicators, reference points, and assessment methods chosen.**
  - Performance indicators: (*\*Complete for each performance indicator*)
    - Data Streams:
    - Target RP
    - Limit RP
    - Assessment method
    - Results/Reasoning:
- **Step 3: Appropriate Fisheries Management Controls**
- **Step 4: Harvest Control Rules**
  - First performance indicators: (*\*Complete for each performance indicator*)
    - Assessment Result:
    - Interpretation (s):
    - Management Implications:
    - HCR suggested in literature:
    - Implemented HCR:
- **Step 5: Interpretations of assessment results**

- First method applied: (*\*Complete this for each method applied*)
    - Results:
    - Interpretations:
  - **Step 6: Complete Adaptive Fishery Management Plan**
    - Adjust fisheries management controls using defined harvest control rules
      - Triggered Harvest Control Rules:
- **Additional Management Measures for the Duration of the Plan:**
  - **Management measures:** Specify if plan is for a single year or multiple years. In the latter case, identify expected management changes in each successive year. Where relevant, include any mandatory financial arrangements required with fish harvesters and other stakeholders.
  - **Monitoring measures** may include:
    - *Observer coverage*
    - *Dockside monitoring*
    - *Logbooks*
    - *Hailing*
    - *Electronic vessel monitoring systems*
  - **Enforcement measures** may include:
    - *Fines*
    - *Sanctions*
    - *Quota revocations*
    - *Vessel suspensions*
    - *Criminal*
- **Stock Scenarios:** Briefly describe expected stock prospects (i.e. trends) for period of the plan, and beyond, if available.
- **Management Plan Performance Review:** Outline indicators that will be used to determine if the plan objectives are met. Where applicable, include results of previous year's review.

## Appendix 1. 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*

## **Appendix 2 Technical Guidance**

Installing the dashboard from the internet

Installing the dashboard from a local file on your computer

Running the FMA Toolkit Dashboard (does not require internet)