Choosing Performance Indicators, identifying Reference Points, and defining Harvest Control Rules

# Choosing Performance Indicators based on Management Tiers (FISHE Step 7)

To manage a fishery, we need to know how it is doing with respect to fishery management goals; in other words, we need Performance Indicators (PIs) that can be measured. While we provide best practices in these steps, it should be noted that Performance Indicators are not one-size-fits-all; they should be based on community goals.

Using [Table 1](#T1), select appropriate Performance Indicators for your fishery. Depending on the data available, your fishery will fall into one of 3 “Management Tiers.” For each management tier, we provide a number of options for the indicators of both fishery sustainability and climate change resilience that you may choose to select. Whenever possible, we recommend that multiple indicators are chosen from multiple independent data streams. This will reduce the uncertainty associated with any single data stream and will paint a more complete picture of the fishery. Use the specific guidance below for your tier.

## Selecting PIs in a Multispecies Fishery

If you are using management baskets to help avoid serial depletion in a multispecies fishery, from this point in the FISHE process onward only the representative species from each basket will be examined. This means that extreme care must be taken when selecting Performance Indicators (PIs) (as well as corresponding Reference Points, below), and when interpreting the results of the assessments (Step 9 and 10).

After PIs have been selected based on goals and data available, ask yourself if trends in the data for the representative species on each PI are likely to characterize/ represent trends for the other species in the basket. In other words, will the various factors (e.g. fishing rate, gear used, etc.) influence all species in the basket in the same way they influence the representative species? Or is there some characteristic of one or more of the other species (e.g., extremely different growth or mortality rates, different spawning behaviors, etc.) that indicate that a given PI result will not mean the same thing as it does for the representative species? It may be necessary to consult with scientists, the fishermen, or other system experts to find answers to these questions.

If you determine that PI values for the representative species may not reflect changes for all species in the basket, it may be necessary to pick a different, or a second, representative species, or to select an alternate PI to assess. Alternatively, the same representative species and PI can be used, but Reference Points can be set at levels that are appropriate for the most vulnerable species in the basket. See below for more information on Reference Points.

**Management Tier 1 – Precautionary Assessment and Management (for sites with less than one year of data)**

Even though limited data will be available for a Tier 1 fishery, managers can still perform a basic qualitative fisheries assessment using local ecological knowledge about the fishery, such as the 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. Potential Performance Indicators for Tier 1 are provided in [Table 1](#T1), along with pros, cons, and the types of species each indicator is appropriate for.

At a minimum, we recommended using the following Performance Indicators for Tier 1:

* At least one indicator based on qualitative fisheries characterization
* If available, at least one indicator based on underwater visual survey

**Tier 2 – Preliminary Adaptive Assessment and Management (for sites with one year of data)**

Data streams in Tier 2 include 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. Potential Performance Indicators for Tier 2 are provided in [Table 1](#T1), along with pros, cons, and the types of species each indicator is appropriate for.

At a minimum, we recommended using the following 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 (for sites with more than one year of data)**

Tier 3 sites will have a time series of data available that can be used to examine trends in multiple Performance Indicators in addition to information and data described under Tiers 1 and 2. Potential Tier 3 Performance Indicators for each available data stream type or toolkit output are provided in [Table 1](#T1), along with pros, cons, and the types of species each indicator is appropriate for.

At a minimum, we recommended using the following 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

# Identifying Reference Points (targets and limits) against which to judge Performance Indicators (FISHE Step 7)

There is no point in measuring the performance of a fishery with Performance Indicators if we can’t tell what the results of our measurements mean: is this level of the Performance Indicator that we find good or bad for the fishery? Does it indicate that we are on track to achieving fishery management goals?

Selecting appropriate Reference Points for each of your chosen Performance Indicators requires inclusive input so that different valued outcomes can be incorporated. [Table 1](#T1) offers suggestions for generic Reference Points from the literature that may be appropriate for some Performance Indicators, but for others it will be necessary to decide on the right RP based on stakeholder values and risk tolerances.

If possible, for every Performance Indicator, select both a target Reference Point (TRP) as well as a limit Reference Point (LRP). A target Reference Point is a numerical value (or trend) that indicates that the performance of the fishery is at a desirable level; often management is geared towards achieving or maintaining this target. This target could be a static value chosen from the literature, or a trend in historic data (for example, a target may be that the indicator is higher than a historic running average). A limit Reference Point is a numerical value that indicates that the performance of the fishery is unacceptable (*e.g*., severely overfished), and that management action should be taken to improve fishery performance or population levels. Similarly, these values may come from the literature or historic data.

When selecting Reference Points, we recommend the following best practices:

* For Reference Points of length-based indicators and of underwater visual survey-based indicators, we recommend using literature-based Reference Points.
* Whenever using Reference Points from literature, use Reference Points from studies of comparable species and geographic locations.
* For CPUE- and landings-based indicators, we recommend using a time series of data to generate Reference Points that are based on trends or running averages.
* If local or international scientists are available for consultation, discuss Reference Points with them to determine if they are appropriate for your fishery and adjust values as necessary.
* Targets and limits should be adjusted according to risk tolerance and uncertainty. If uncertainty is high, for example because only one or two years of data are available, targets and limits should be more conservative to reduce the risk of overfishing.

For a good guide on how to set Reference Points, also refer to <http://www.fao.org/docrep/003/v8400e/V8400E02.htm>.

## Selecting RPs in a Multispecies Fishery

As discussed above, the selection of Performance Indicators (PIs) and identification of appropriate Reference Points (RPs) is somewhat more complex in a multispecies fishery where management baskets are being used. In these cases, managers must ask themselves if PIs and RPs selected for the representative species for each basket will accurately represent trends and changes for the other species in the basket(s).

In some cases, a given PI may be suitable for all species in a basket, but different RPs may be appropriate for some species. For example, if Spawning Potential Ratio (SPR) is the selected PI, the appropriate target RP is 0.20 for fast growing species, and 0.40 for slow growing species. Thus, if a given management basket contains species with a wide range of growth rates managers must be careful to choose an RP for analysis that doesn’t put the slower growing species at risk, even if the representative species has a faster growth rate. In this example, an RP of 0.40 can be selected (regardless of the growth rate of the representative species) to be precautionary, or if managers have a slightly higher risk-tolerance, an RP of 0.30 could be selected as a mid-point between the fast and slow growing species’ SPR targets.

# Defining Harvest Control Rules (HCRs) (FISHE Step 8)

*How should fishery management be adjusted according to the Performance Indicators of the fishery goals?*

To make science-based fishery management decisions, we need *Harvest Control Rules (HCRs)*, which are simply rules that tell managers what to do when Performance Indicators are found to be near their targets, far from their targets, near their limits, or beyond their limits. The HCR specifies some adjustment, or some combination of adjustments, to the way the fishery is managed that is expected to move the chosen Performance Indicators towards their Target Reference Points, and away from their Limit Reference Points**,** therefore improving the performance of the fishery. For example, if stakeholders choose to track the percent of the catch made up of juveniles as their Performance Indicator, the HCR might direct that if this PI is not near its Target, or (worse) if it has passed its Limit, the fishery should reduce its catch of under-sized fish. In a multispecies fishery, these rules would be triggered by data on the representative species for each management basket, but the specified actions would pertain to all species in that basket.While we provide guidance to define HCRs, it should be noted that HCRs should be based on realistic compliance and enforcement concerns and address community goals for your fishery.

HCRs are not the same as specific “management measures” or “fishery regulations” that dictate specific changes in fishery management. Instead, they are simple rules that say “if we find that our fishery is in X condition, we will do Y.” For example, if assessments reveal that the Performance Indicators selected for your fishery are all falling short of their target Reference Points (indicating that the fishery is over-exploited, and/ or that the fishery is unsustainable), one potential HCR would be simply to “reduce fishing mortality” in an effort to restore depleted stocks. The HCR does *not* say (for example) “we will reduce fishing mortality *by reducing quotas*,” or “*by closing spawning grounds to fishing*,” or “*by changing gears*,” or “*by closing the fishery*.” Each of these is an example of a specific management *measure* that stakeholders might select to achieve the change indicated by the HRC. We will discuss the selection of management measures, based on interpretation of the results of our assessments that let us compare our Performance Indicators to our Reference Points, in later steps (Steps 10 and 11).

It is important for stakeholders and managers to agree on a suite of HCRs in a safe and neutral setting before any management decisions need to be made (i.e., before the results of the assessments come out). 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. See [Table 5](#_Table_5:_Example) for an example.

## Step 8a – Define general harvest control rules for all possible combinations of PI results

The first step in creating effective HCRs is for stakeholders to consider every possible combination of Performance Indicator-to-Reference Point (PI:RP) measurement that may result when you assess your fishery and defining general HCRs for each one (for example, “if all Performance Indicators selected are below their target Reference Points (RPs), reduce the total allowable catch”). We recommend selecting more than one PI to improve confidence in the interpretation of results. Because of the different data streams, assessment methods, and fishery components represented by each PI, it is possible that assessment results will reveal some PIs falling above their targets, while others fall below them.

Each possible combination of PI results is called a “scenario.” For example, in “scenario 1,” both PIs selected may be above their limit Reference Points and near their target Reference Points, indicating that the fishery is performing well, and the stock is healthy. In “scenario 2” the first PI may be above its limit, but the second may be below its limit. The interpretation of this mixed scenario will depend on the PIs under analysis, the data and assessment methods used, and the characteristics of the fishery itself. It is important that all stakeholders work together to define an HCR for every foreseeable scenario (every possible combination of PI measurement results relative to corresponding RPs) so that management responses can be transparent and objective when the time comes to implement them.

[Table 2](#T2), [Table 3](#T3), and [Table 4](#T4) can be used as the framework for defining your general HCRs. These three tables contain the Performance Indicators that are associated with each management tier and suggest HCRs from the literature. For each Performance Indicator and assessment result, the table lists a number of potential interpretations and corresponding HCRs. These tables provides some examples, but they are by no means comprehensive or prescriptive – they are illustrative only.

Each row of Tables 2 - 4 also has a stoplight indicator that describes if a management response is necessary:

* + Green circles () indicate that either no management response is necessary, or management could be even less restrictive.
  + Yellow circles () indicate that a precautionary management response should be considered.
  + Red circles () indicate that a management response is necessary.
  + Black circles () indicate that the fishery should be closed and a fishery recovery plan implemented.

We have provided blank HCR tables as Excel worksheets (in your workbook) to aid the process of defining HCRs with fishery stakeholders. Fill out the HCR table that corresponds to the number of PIs you have selected (or, if you have selected more than three HCRs, you may create your own HCR table following our format. Select from the HCRs that we provide in Tables 2 – 4, or design your own HCRs that you feel will be most appropriate for the specific characteristics of your fishery. [Table 5](#T5) provides an example of a completed HCR table with three PIs, which can be used for further guidance.

## Step 8b – Add specificity to harvest control rules

Next it is necessary to add specificity to your HCRs (for example, 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 fishery management measures should be adjusted given the relationship of the fishery’s Performance Indicator to its Reference Point.

The magnitude that a HCR should adjust your management measure(s) will depend on:

1. Productivity (life history) of the target species
   1. This information may either come from a PSA result or a more data-limited qualitative approach for assessing species productivity.
   2. 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,
   1. The more uncertain you are, the more precautionary you may want to make your management
6. Risk tolerance.
   1. 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.

You should consult any existing data that 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.

# Table 1: Selecting your Performance Indicators and Reference Points

| **Tier** | | | | **Data stream Options** | **Performance Indicator Options** | **Target Reference Point** | **Limit Reference Point** | **Assessment Methods** | **Target Species** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **3** | **2** | **1** | |
|  |  | |  | ***Fishery Characterization Survey*** | **DESTRUCTIVE FISHING GEAR**  *Pros*: relatively easy metric to monitor using local ecological knowledge  *Cons*: None | No destructive fishing practices being used | Destructive fishing practices being used | Qualitative assessment of Fishery Characterization Survey | All fish and invertebrates |
| **FISHING SEASON**  *Pros*: relatively easy metric to monitor using local ecological knowledge  *Cons*: Changes in fishing season do not always indicate poor fisheries performance; this may also result from changing environmental or market conditions | No changes in the fishing season | Increased variability in fishing season, or decreased fishing season | Qualitative assessment of Fishery Characterization Survey | All fish and invertebrates |
| **TARGET SPECIES COMPOSITION**  *Pros*: relatively easy metric to monitor using local ecological knowledge  *Cons*: Changes in target species composition do not always indicate poor fisheries performance; this may also result from changing market or environmental conditions (e.g., climate change) | No change in composition of caught species | Change in composition of caught species (fewer species, more pelagics) or loss of major fishing targets, predators and grazers | Qualitative assessment of Fishery Characterization Survey | All fish and invertebrates |
| ***PSA*** | **SPECIES VULNERABILITY**  *Pros*: 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 action/assessments  *Cons*: is not an estimate of stock status | Low vulnerability estimate (< 2.0 PSA score); low- medium susceptibility and high-medium productivity species are a lower priority for management action relative to species with higher vulnerability estimates (>2.0 PSA score) | High vulnerability estimate (> 2.0 PSA score); high susceptibility and medium or low productivity species should be high priority for management action and frequent assessment | Productivity & Susceptibility Analysis | All fish and invertebrates present in the ecosystem |
| ***Underwater Visual Surveys*** | **CHANGE IN SPECIES COMMUNITY COMPOSITION/ MIX (DENSITY OF DIFFERENT SPECIES IN THE WATER)**  *Pros:* a wholistic indicator of system change.  *Cons:* cannot tell you *why* changes are happening (e.g., fishing pressure, climate change, etc.). Also requires multiple surveys or some other baseline data on species community makeup. | No change | 80% different from historic species mix | Comparison of visual density surveys | Fish and invertebrates that are habitat associated, not a good indicator for highly mobile targets |
| **CHANGE IN EXTENT OR HEALTH OF KEY HABITAT TYPES**  *Pros:* easier to observe than changes in species community composition. Metric of change that may impact may species.  *Cons:* “Lagging indicator,” meaning once the habitats have moved or been degraded the change is well-advanced. | Less than 10% negative change from historic levels of habitat metrics | Greater than 10% negative change from historic levels of habitat metrics | Comparison of visual surveys | All species, especially habitat-associated species |
| **FISHED: UNFISHED DENSITY RATIO (FOR KEY TARGET SPECIES OR CLIMATE VULNERABLE SPECIES)**  *Pros*: a relatively quick and cheap way to assess the status of target species.  *Cons*: assumes that a fully-functioning and well-enforced NTZ has been sited appropriately with representative habitat, not useful for highly mobile targets. | Fished:unfished density of target species > 0.6 | Fished:unfished density of target species < 0.4 | Density Ratio | Fish and invertebrates that are habitat associated, not a good indicator for highly mobile targets |
| **FISHED: UNFISHED BIOMASS RATIO (CORAL REEF THRESHOLD AGGREGATED ACROSS SPECIES)**  *Pros*: provides an estimate of ecosystem status and capacity to support fishing, useful for setting precautionary management to meet EBFM goals.  *Cons*: 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. | Fished:unfished biomass ratio > 0.5 | Fished:unfished biomass ratio < 0.25 | Coral Reef Thresholds | Multi-species finfish fishery |
|  | ***Fishery Dependent Length-Composition Survey*** | **FISHING MORTALITY (F)**  *Pros*: mortality rates are critical for determining abundance of fish populations  *Cons*: 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. | F/M <1 (F is fishing mortality, M is natural mortality) | F=2M | Catch Curve | Finfish (groupers, snapper, grunts, etc.), and invertebrates with determinant growth (lobsters, crabs). Use with care for targets that have deterministic growth and episodic recruitment. |
| Mean Length (Lbar) |
| Bounded Mean Length Mortality Estimator |
| Mean Weight Mortality Estimator |
| **SPAWNING POTENTIAL RATIO (SPR)**  *Pros*: can be used with fishery independent and dependent data.  *Cons*: Assumes equilibrium conditions and a 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. | *slow growing species, M/k< 1 (grouper) SPR > 40% (M is natural mortality, k is von Bertalanffy growth rate)*  *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) | Finfish (groupers, snapper, grunts, etc.), and invertebrates with determinant growth (lobsters, crabs). Use with care for targets that have deterministic growth and episodic recruitment. |
| **AVERAGE LENGTH IN CATCH**  *Pros*: easy, cheap metric to assess changes in the status of a fishery when stratified across sampling unit (gear, efforts, fishing zone)  *Cons*: With little to no historical information on the length of the catch or with no information on gear selectivity, the average length could biases the expected potential size distribution. | Increase in average length | Decrease in average length or mature adults | Average Length | All targets, especially nearshore targets. In an ideal scenario an historic record of average length would be used to compare current to past estimates. |
| **FROESE INDICATORS**  *Pros*: proved estimate of the status of the stock, in comparison to sustainability Reference Points  *Cons*: does not contribute to biomass sustainability Reference Points | 100% of catch – optimal  < 10% of the catch are *megaspawners*  90% of the catch are mature adults | <80% of catch – optimal  < 20% of the catch are *megaspawners*  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*** | **PROPORTIONS OF CATCH MADE UP OF CLIMATE-VULNERABLE SPECIES**  *Pros:* easy, cheap metric to track changes in abundance (or size) of climate-vulnerable species.  *Cons:* “lagging indicator,” meaning by the time their numbers are declining in the stock system changes may be well-advanced. Also, changes may be due to fishing pressure or climate change, indicator cannot distinguish. | Within 10% of historical percentage | Greater than 50% change from historical percentage | Catch Trends | All targets that are vulnerable to climate change (as determined by separate assessment) |
| **CHANGE IN LOCATION OF HIGH-CATCH AREAS (OR “EDGES” OF CATCH AREAS)**  *Pros:* good indicator of species range shifts that can provide input to cross-jurisdictional management coordination.  *Cons:* perceived shifts may be result of fisher preferences and behavior rather than environmental change. | No change | Greater than 10 km change | Surveys of fishers | All targets with well-known common catch areas. |
| **CPUE**  *Pros*: can be used to infer population trends of an exploited stock. Standardized time series of CPUE are often regarded as indices of abundance.  *Cons*: seldom proportional to abundance history and an entire geographic range. Can be skewed, depending on sampling regime. May have species-specific biases. | Stable CPUE | Rapidly Decreasing CPUE, previous year or in comparison to running average | Catch Trends | All targets that do not have high selectivity of habitat stratification. |
| **TOTAL LANDINGS**  *Pros*: when sampling is stratified, can provide an estimate of abundance  *Cons*: seldom proportional to abundance history and an entire geographic range, because of fishing location biases and lack of sampling stratification | Increase in Total Landing | Rapidly Decreasing Total Landings, previous year or in comparison to running average | Catch Trends | All targets that do not have high selectivity of habitat stratification. |

# Table 2: Indicators for Tier 1 with possible interpretations, management implications, and suggested harvest control rules

| ***For each*** Performance Indicator… | ***If*** the assessment result is this… | ***And***you believe the interpretation is likely this… | ***Then***the management implication is this… | ***And then*** the Harvest Control Rule suggested in the literature is this… |
| --- | --- | --- | --- | --- |
| Fishing Gear | 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 ***or*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.) |
| Fishing Season | 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., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.) |
| No changes in the fishing season | Ecosystem may be healthy enough to support historical fishing season |  | 1. If there is no reason to believe precautionary management is necessary, make no changes to fisheries management controls ***or*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.) |
| Target Species Composition | Change in composition of caught species (fewer species, more pelagics) | Ecosystem likely not healthy enough to support historical target species |  | 1. Make fisheries management controls more restrictive (i.e., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.) |
| No change in composition of caught species | Ecosystem may be healthy enough to support historical target species |  | 1. If there is no reason to believe precautionary management is necessary, make no changes to fisheries management controls ***or*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.) |
| Species Vulnerability | Target species have high vulnerability | Target species have high susceptibility and/or low 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 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 ***or*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.) |
| Change in species community composition/ mix (Density of different species in the water) | Species community has not changed noticeably from historic baseline | Serial depletion through overfishing of “weaker” stocks is not occurring. Climate change is not (yet) impacting the ranges or productivity rates of species in your area. |  | 1. Make no changes to management 2. Continue to monitor PI(s) |
| Species community has changed significantly from historic baseline | Overfishing or climate change is impacting at least some species’ productivity rates and/or ranges; new species may be moving in while old species move out or die off. |  | 1. Assess and address barriers to fisher mobility that will allow catch in new locations    1. Begin discussions with neighboring jurisdictions/ countries about how to manage stocks if they shift across management boundaries 2. Evaluate vulnerability of, and begin assessment and management cycle for, new stocks 3. Put new stocks into management baskets |
| Change in extent or health of key habitats | No noticeable change in key habitats compared to historic baseline | Climate change or other ecosystem stressors (e.g., pollution) not (yet) negatively impacting ecosystems that underpin the fishery. |  | 1. Evaluate full suite of existing system stressors and attempt to reduce or eliminate as many as possible. 2. Identify “climate refugia” based on expected patterns of climate change impact and protect them. 3. Continue to monitor PI(s). |
| Key habitats noticeably degraded, truncated, or shifted compared to historic baseline. | Climate change and/ or other ecosystem stressors reducing the ability of the ecosystem to continue to support the fishery and community wellbeing. |  | 1. Evaluate what, if any, system stressors can be managed or reduced. 2. Identify “climate refugia” – areas where habitats are less degraded – and protect them. 3. Explore ecosystem restoration options as possible. 4. Assess and address barriers to fisher mobility that will allow catch in new locations    1. Begin discussions with neighboring jurisdictions/ countries about how to manage stocks if they shift across management boundaries |
| Fished:unfished density ratio (for key target species) | Indicator >= Target | Fishing pressure appropriate for maintaining or improving the health of the ecosystem |  | 1. Make no changes to fisheries management controls ***or*** 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 virgin area (significant illegal fishing is occurring within the NTZ) |  | 1. Consider improved enforcement of NTZ ***and*** 2. Consider targeted social marketing to improve compliance with NTZ ***and*** 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 density and does not represent a healthy virgin 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 virgin area (NTZ is small with large amounts of species movement between fished and unfished areas) |  | 1. Consider expansion or relocation of NTZ ***and*** 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.) |
| Unfished area has a low density and does not represent a healthy virgin area (significant illegal fishing is occurring within the NTZ) |  | 1. Consider improved enforcement of NTZ ***and*** 2. Consider targeted social marketing to improve compliance with NTZ ***and*** 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 density and does not represent a healthy virgin 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 virgin area (NTZ is small with large amounts of species movement between fished and unfished areas) |  | 1. Consider expansion or relocation of NTZ ***and*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.) |
| Limit >= Indicator | High fishing pressure has caused an ecosystem state change; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |
| Extreme environmental stochasticity has caused an ecosystem state change; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |
| Coral Reef Thresholds (aggregated across species) | Unfished biomass Indicator >= Target  ***And***  fished:unfished biomass ratio >= Target | Fishing pressure appropriate for maintaining or improving the health of the ecosystem |  | 1. Make no changes to fisheries management controls ***or*** 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 virgin area (significant illegal fishing is occurring within the NTZ) |  | 1. Consider improved enforcement of NTZ ***and*** 2. Consider targeted social marketing to improve compliance with NTZ ***and*** 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 virgin 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 biomass and does not represent a healthy virgin area (NTZ is small with large amounts of species movement between fished and unfished areas) |  | 1. Consider expansion or relocation of NTZ ***and*** 2. 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 does not have comparable habitat to fished area (unfished area habitat not as healthy as fished area) |  | 1. Consider expansion or relocation of NTZ ***and*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.) |
| Limit <= Unfished biomass Indicator <= Target  ***And***  Limit <= fished:unfished biomass ratio <= Target | 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.) |
| Unfished area has a low density and does not represent a healthy virgin area (significant illegal fishing is occurring within the NTZ) |  | 1. Consider improved enforcement of NTZ ***and*** 2. Consider targeted social marketing to improve compliance with NTZ ***and*** 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 density and does not represent a healthy virgin 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 virgin area (NTZ is small with large amounts of species movement between fished and unfished areas) |  | 1. Consider expansion or relocation of NTZ ***and*** 2. 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 does not have comparable habitat to fished area (unfished area habitat not as healthy as fished area) |  | 1. Consider expansion or relocation of NTZ ***and*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.) |
| Limit >= Unfished biomass Indicator  ***Or***  Limit >= fished:unfished biomass ratio | High fishing pressure has caused an ecosystem state change; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |
| Extreme environmental stochasticity has caused an ecosystem state change; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |

# Table 3: Indicators for Tier 2 with possible interpretations, management implications, and suggested harvest control rules

| ***For each*** Performance Indicator… | ***If*** the assessment result is this… | ***And***you believe the interpretation is likely this… | ***Then***the management implication is this… | ***And then*** the Harvest Control Rule suggested in the literature is this… |
| --- | --- | --- | --- | --- |
| Fishing Mortality (F) | Indicator >= Limit | High fishing pressure negatively affecting size structure and spawning stock biomass; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |
| Extreme environmental stochasticity negatively affecting size structure and spawning stock biomass; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |
| Limit > Indicator > Target | High fishing pressure affecting size structure and spawning stock sbiomass |  | 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.) |
| Gear shift towards less selective gear (more small individuals in catch) |  | 1. Consider implementing a gear restriction on less selective gear ***and/or*** 2. Consider implementing a minimum size limit (if one does not already exist) |
| Strong recruitment pulse (more small individuals entering the catch) |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Market selectivity for smaller individuals |  | 1. Consider implementing a minimum size limit (if one does not already exist) |
| 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 |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Gear shift towards more selective gear (fewer small individuals in catch) |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Market selectivity for larger individuals |  | 1. Consider implementing a maximum size limit (if one does not already exist) |
| 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 |
| Average Length | Indicator <= Limit | High fishing pressure negatively affecting size structure and spawning stock biomass; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |
| Extreme environmental stochasticity negatively affecting size structure and spawning stock biomass; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |
| Limit < Indicator < Target | 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.) |
| Gear shift towards less selective gear (more small individuals in catch) |  | 1. Consider implementing a gear restriction on less selective gear ***and/or*** 2. Consider implementing a minimum size limit (if one does not already exist) |
| Strong recruitment pulse (more small individuals entering the catch) |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Market selectivity for smaller individuals |  | 1. Consider implementing a minimum size limit (if one does not already exist) ***or*** 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 |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Gear shift towards more selective gear (fewer small individuals in catch) |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Market selectivity for larger individuals |  | 1. Consider implementing a maximum size limit (if one does not already exist) ***or*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.) |
| 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 |
| Spawning Potential Ratio | Indicator <= Limit | High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |
| Extreme environmental stochasticity affecting size structure and spawning stock biomass; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |
| Limit > Indicator < Target | 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.) |
| Gear shift towards less selective gear (more small individuals in catch) |  | 1. Consider implementing a gear restriction on less selective gear ***and/or*** 2. Consider implementing a minimum size limit (if one does not already exist) |
| Strong recruitment pulse (more small individuals entering the catch) |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Market selectivity for smaller individuals |  | 1. Consider implementing a minimum size limit (if one does not already exist) ***or*** 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 ***or*** 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 ***or*** 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.) |
| Market selectivity for larger individuals |  | 1. Consider implementing a maximum size limit (if one does not already exist) ***or*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.) |
| 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 ***or*** |
| Froese Indicators | 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 |  | 1. Make no changes to fisheries management controls ***or*** 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 or less selective gear |  | 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 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  ***And/or***  Target > Lmat > Limit | Market selectivity for smaller individuals |  | 1. Consider implementing a minimum size limit (if one does not already exist) ***or*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.) |
| 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.) |
| Strong recruitment pulse (more small individuals entering the catch) |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| 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., increase TAC, increase allowable effort, add or modify certain controls, etc.) |
| Limit > Lmega > Target | Market selectivity for larger individuals |  | 1. Consider implementing a maximum size limit (if one does not already exist) ***or*** 2. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.) |
| 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.) |
| 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 ***or*** |
| Lopt < Limit (Lopt<80%) | High fishing pressure affecting size structure and spawning stock biomass; fishery in danger of collapse |  | 1. Close fishery ***and*** 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 ***and*** 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 ***and*** 2. Implement fishery recovery plan |

# Table 4: Indicators for Tier 3 with possible interpretations, management implications, and suggested harvest control rules

| ***For each*** Performance Indicator… | ***If*** the assessment result is this… | ***And***you believe the interpretation is likely this… | ***Then***the management implication is this… | ***And then*** the Harvest Control Rule suggested in the literature is this… |
| --- | --- | --- | --- | --- |
| Proportion of catch made up of climate-vulnerable species | Indicator >= Target | Climate change not (yet) impacting vulnerable species’ ranges or productivity rates. |  | 1. Continue to monitor PIs 2. (Optionally) assess SPR or other PI to understand status of climate-vulnerable species |
| Target > Indicator > Limit | Climate change may be beginning to impact the range and/or productivity rate(s) of climate-vulnerable target species, making them harder or easier to catch. |  | 1. Assess SPR or other PI to understand status of climate-vulnerable species    1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.) 2. Assess and address barriers to fisher mobility that will allow catch in new locations    1. Begin discussions with neighboring jurisdictions/ countries about how to manage stocks if they shift across management boundaries 3. Assess and address barriers to fisher flexibility that will allow catch of new species    1. Explore opportunities throughout the supply chain to help match demand with expected supply |
| Limit >= Indicator | Climate change has significantly impacted the range and/or productivity rate of climate-vulnerable target species. |  | 1. Assess SPR or other PI to understand status of climate-vulnerable species    1. Consider making fisheries management controls more restrictive (i.e., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.) if health is declining 2. Assess and address barriers to fisher mobility that will allow catch in new locations    1. Implement cross-jurisdictional management with neighboring jurisdictions/ countries 3. Assess and address barriers to fisher flexibility that will allow catch of new species    1. Explore opportunities throughout the supply chain to help match demand with expected supply |
| Change in location of high-catch areas (or “edges” of catch areas) | Indicator >= Target | Climate change not (yet) impacting target species’ ranges. |  | 1. Continue to monitor PIs 2. (Optionally) assess SPR or other PI to understand status of target species . |
| Target > Indicator > Limit | Climate change may be beginning to impact the range of target species. |  | 1. Assess SPR or other PI to understand status of target species.    1. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.) 2. Assess and address barriers to fisher mobility that will allow catch in new locations    1. Begin discussions with neighboring jurisdictions/ countries about how to manage stocks if they shift across management boundaries 3. Assess and address barriers to fisher flexibility that will allow catch of new species    1. Explore opportunities throughout the supply chain to help match demand with expected supply |
| Limit >= Indicator | Climate change has significantly impacted the range of target species. |  | 1. Assess SPR or other PI to understand status of climate-vulnerable species    1. Consider making fisheries management controls more restrictive (i.e., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.) if health is declining 2. Assess and address barriers to fisher mobility that will allow catch in new locations    1. Implement cross-jurisdictional management with neighboring jurisdictions/ countries 3. Assess and address barriers to fisher flexibility that will allow catch of new species    1. Explore opportunities throughout the supply chain to help match demand with expected supply |
| CPUE | Indicator >= Target | Fishing pressure appropriate for maintaining or improving spawning stock biomass |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Change to more efficient gear type |  | 1. Consider implementing a gear restriction on less selective gear ***and/or*** 2. Consider implementing a minimum size limit (if one does not already exist) |
| Serial depletion (fishers have moved from depleted fishing grounds to less depleted fishing grounds, such as offshore areas) |  | 1. Make fisheries management controls more restrictive (i.e., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.) |
| Misreporting of effort; reported effort too low |  | 1. Modify catch reporting protocols ***and/or*** 2. Perform social marketing dedicated towards increasing catch reporting compliance ***and*** 3. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.) |
| Fishing of spawning aggregations / hyperstability |  | 1. Ban fishing of spawning aggregations |
| Target > Indicator > Limit | Environmental stochasticity negatively affecting spawning stock biomass |  | 1. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.) |
| Change to less efficient gear type |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Misreporting of effort; reported effort too high |  | 1. Modify catch reporting protocols ***and/or*** 2. Perform social marketing dedicated towards increasing catch reporting compliance ***and*** 3. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.) |
| High fishing pressure negatively affecting spawning stock biomass |  | 1. Make fisheries management controls more restrictive (i.e., increase TAC, increase effort cap, add or modify certain controls, expand NTZ, etc.) |
| Limit >= Indicator | High fishing pressure negatively affecting spawning stock biomass; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |
| Previous Year’s Total Landings | Indicator >= Target | Fishing pressure appropriate for maintaining or improving spawning stock biomass |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Fishing effort increased last year |  | 1. Consider precautionary management by making fisheries management controls more restrictive (i.e., increase TAC, increase allowable effort, add or modify certain controls, etc.) |
| Misreporting of landings; reported catch too high |  | 1. Modify catch reporting protocols ***and/or*** 2. Perform social marketing dedicated towards increasing catch reporting compliance ***and*** 3. 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 negatively affecting 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.) |
| Fishing effort decreased last year |  | 1. Make no changes to fisheries management controls ***or*** 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.) |
| Misreporting of landings; reported catch too low |  | 1. Modify catch reporting protocols ***and/or*** 2. Perform social marketing dedicated towards increasing catch reporting compliance ***and*** 3. Consider precautionary management by making fisheries management controls more restrictive (i.e., decrease TAC, decrease allowable effort, add or modify certain controls, etc.) |
| Limit >= Indicator | High fishing pressure negatively affecting spawning stock biomass; fishery in danger of collapse |  | 1. Close fishery ***and*** 2. Implement fishery recovery plan |

# Table 5: Example Harvest Control Rules for Three PI/RP combinations for Fishery Sustainability and Climate Resilience Goals

| **Scenario** | **PIs and RPs for Fishery Sustainability goals** | | | **Interpretation / possible causes** | **Harvest Control Rules and other Management Guidance** | **PIs and RPs for Climate Resilience goals** | | | **Interpretation / possible causes** | **Management Guidance** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PI:RP** | **MPA Density Ratio ≥ 0.50** | **F ≤ M** | **SPR ≥ 0.40** |  |  | **SPR of most climate vuln. Sp ≥ 0.40** | **Change in location of areas of high abundance < 10km** | **Species mix ≥ 80% similar to historic** |  |  |
| **1** | **✓** | **✓** | **✓** | * Stock healthy with good productivity, and fishery performance sustainable | *No response required, but optionally:*   1. Monitor reference point (RP) trends 2. Make no change (if RP trends are stable or just above limits) 3. Increase fishing mortality if MPA density ratio is increasing, F is decreasing, and SPR is increasing | **✓** | **✓** | **✓** | * Climate change not yet impacting species’ ranges, health, or productivities * No new species entering the fishery | *No response required, but:*   1. Continue to monitor PIs 2. (Optionally) assess SPR of another climate-vulnerable species |
| **2** | **✓** | **X** | **✓** | * Increased pressure or new gear * Sampling bias that increases F * Large recruitment pulse | *Response required; recommended action sequence:*   1. Confirm/monitor F values with multiple models/approaches 2. No change (if F trends are stable/near limit) 3. Reduce fishing mortality to reduce risk of overfishing | **✓** | **X** | **✓** | * Climate change not yet impacting species’ productivities or health * Local stock ranges may be shifting * No new species entering the fishery | *Response required:*   1. Assess and address barriers to fisher mobility that will allow catch in new locations    1. Begin discussions with neighboring jurisdictions/ countries about how to manage stocks if they shift across management boundaries |
| **3** | **X** | **✓** | **✓** | * Fishing rate sustainable and stock productivity healthy, but stock density at unhealthy levels/ approaching threshold * Stock density could be low due to non-fishing factors or historical fishing impacts * Error in calculations? | *Response required; recommended action sequence:*   1. Monitor MPA density ratio, F and SPR trends and recruitment, gear and behavior patterns 2. Make no change if MPA density ratio stable or increasing and F and SPR trends stable/just above limits, 3. Reduce fishing mortality if MPA density ratio decreasing, F trend increasing, SPR trend decreasing | **X** | **✓** | **✓** | * Overfishing or climate has reduced reproductive potential of climate vulnerable * Ranges not changing and new stocks not entering the fishery | *Response required:*   1. Evaluate other stock-specific PIs for climate vulnerable stocks    1. Reduce fishing mortality on climate vulnerable stocks if other PIs corroborate finding of overfished status |
| **4** | **X** | **X** | **✓** | * Potential early warning of growth and recruitment overfishing * Stock potentially nearing threshold * Large recruitment pulse | *Response required; recommended action sequence:*   1. Confirm/monitor SPR values with multiple models/approaches 2. No change (if SPR trends are stable/near limit) 3. Reduce fishing mortality | **X** | **X** | **✓** | * Overfishing or climate has reduced reproductive potential of climate vulnerable * Local stock ranges may be shifting * New species are not yet entering fishing grounds | *Response required:*   1. Evaluate other stock-specific PIs for climate vulnerable stocks    1. Reduce fishing mortality on climate vulnerable stocks if other PIs corroborate finding of overfished status 2. Assess and address barriers to fisher mobility that will allow catch in new locations    1. Begin discussions with neighboring jurisdictions/ countries about how to manage stocks if they shift across management boundaries |
| **5** | **✓** | **✓** | **X** | * Abundance levels are healthy, overfishing is not occurring, yet SPR is low * F or SPR estimate(s) in error? | *Response required; recommended action sequence:*   1. Confirm/monitor SPR with multiple models/approaches 2. If SPR continues to be low, consider additional regulatory options to reduce fishing pressure | **✓** | **✓** | **X** | * Climate change not yet impacting species’ local productivities or health * Local stock ranges not shifting * New species are entering fishery OR old species are exiting and altering catch mix | *Response required*   1. Evaluate vulnerability of, and begin assessment and management cycle for, new stocks    1. Put new stocks into management baskets 2. (Optionally) assess SPR of another climate-vulnerable species |
| **6** | **X** | **✓** | **X** | * Overfishing may be occurring, resulting in reduced abundance and egg production, or * Error in calculations | *Response required; recommended action sequence:*   1. Confirm/monitor SPR with multiple models/approaches 2. Reduce fishing mortality 3. If trend persists consider additional regulatory options to reduce fishing pressure | **X** | **✓** | **X** | * Overfishing or climate has reduced reproductive potential of climate vulnerable * Local stock ranges not shifting * New species are entering fishery OR old species are exiting and altering catch mix | *Response required*   1. Evaluate other PIs to corroborate overfished status    1. Reduce fishing mortality if corroborated 2. Evaluate vulnerability of, and begin assessment and management cycle for, new stocks 3. Put new stocks into management baskets |
| **7** | **✓** | **X** | **X** | * Overfishing is occurring * Increased targeting, resulting in high fishing mortality that has not yet manifested as a detectable change in abundance, or * Error in calculations | *Response required; recommended action sequence:*   1. Confirm/monitor SPR with multiple models/approaches 2. Reduce fishing mortality 3. If trend persists consider additional regulatory options to reduce fishing pressure | **✓** | **X** | **X** | * Climate change not yet impacting species’ local productivities or health * Local stock ranges may be shifting * New species are entering fishery OR old species are exiting and altering catch mix | *Response required:*   1. Assess and address barriers to fisher mobility that will allow catch in new locations    1. Begin discussions with neighboring jurisdictions/ countries about how to manage stocks if they shift across management boundaries 2. Evaluate vulnerability of, and begin assessment and management cycle for, new stocks 3. Put new stocks into management baskets |
| **8** | **X** | **X** | **X** | * Overfishing is occurring * The stock is overfished | *Response required; recommended action sequence:*   1. Confirm/monitor SPR with multiple models/approaches 2. Reduce fishing mortality 3. If trend persists, consider additional regulatory options to reduce fishing pressure | **X** | **X** | **X** | * Overfishing or climate has reduced reproductive potential of climate vulnerable stocks, * Local stock ranges may be shifting * New species are entering fishery OR old species are exiting and altering catch mix | *Response required:*   1. Evaluate other PIs to corroborate overfished status    1. Reduce fishing mortality if corroborated 2. Assess and address barriers to fisher mobility that will allow catch in new locations    1. Begin discussions with neighboring jurisdictions/ countries about how to manage stocks if they shift across management boundaries 3. Evaluate vulnerability of, and begin assessment and management cycle for, new stocks 4. Put new stocks into management baskets |