Adaptive Fisheries Management for Nearshore Fisheries

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"If you don't know where you're going, you'll end up someplace else" -Yogi Berra

Introduction

Effective management of marine capture fisheries promotes social and economic returns to fishery stakeholders while maintaining a portfolio of ecosystem benefits that society values. For some fisheries, management actions are determined using quantitative stock assessments to estimate the status of the resource relative to predefined targets or "reference points," such as the biomass that achieves maximum sustainable yield (Walters and Martell 2002). However, more than 80% of global fisheries catch occurs in fisheries that lack the necessary data, resources, infrastructure, and expertise to use conventional stock assessment models to set sustainable management actions (Costello et al 2012). Instead, these fisheries often go unmanaged, or are managed with little scientific input, resulting in suboptimal harvest rates, ineffective regulations, and poor social and economic welfare for communities dependent on fishing.

Management decisions in data- and resource-limited situations regarding *how* to appropriately adjust fishing pressure, and by *how much*, can be the most difficult assignment managers must undertake. Too often, fisheries are not managed at all or management measures are based on standard practices without an adequate scientific basis; this creates a high risk of overfishing and the loss of economic and social benefits from fisheries. Here we describe a way to make fishery management decisions based on science, even when data and capacity are limited. Designing this adaptive management framework starts by defining goals for key target species or ecosystem values using the input of both managers and stakeholders (e.g., fisherman, non-profits, etc.). Based on these goals, appropriate indicators are chosen that can be quantified using the available data. Data limited stock assessments (DLSAs) can be used to inform indicators within this framework in lieu of conventional stock assessments. Based on these indicators, reference points such as overfishing thresholds are specified. Through the use of harvest control rules, managers and stakeholders evaluate the indicators against the reference points, interpret the results together, and choose appropriate management actions aimed at achieving the stated goals. The indicators are re-evaluated each year to determine the status of the fishery and to help managers and stakeholders decide whether management changes are necessary or not (Figure 1).

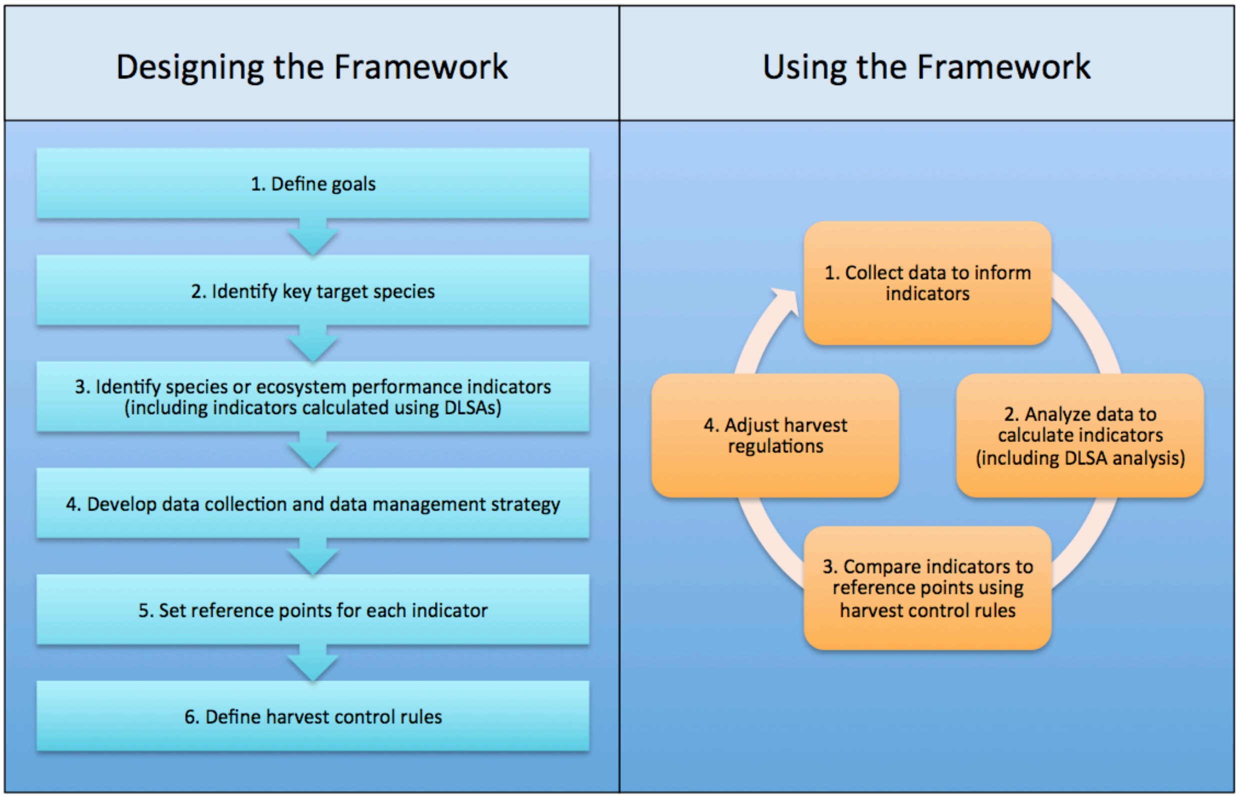

Figure 1: Designing and using an adaptive fisheries management framework

In addition to being useful in data- and resource-limited situations, managing adaptively is important due to the dynamic nature of fisheries. Fisheries are highly dynamic processes involving fluctuating environmental conditions, dynamic fishing behaviors, variable productivity of the resource, and changing market and economic conditions. As a result, fisheries management must be designed to be flexible and adaptive to changing conditions. Developing a robust adaptive management framework provides managers with the means to re-evaluate and adjust decisions periodically based on observations about fishery conditions and from learning from the outcomes of previous management decisions. Adaptive learning and management are essential in moving towards successful management in communities with limited data and resources.

Data limited stock assessments (DLSAs) and their use in adaptive fisheries management

There has been a renewed interest in using 'data limited stock assessments' to inform an adaptive approach to fisheries management for fisheries with limited data. Data limited stock assessments have a long history of use, albeit under different names and using different methods. Data limited assessment methods have been developed that rely on measurements of individual fish lengths (Ault et al 2012, Gedamke and Hoenig 2006), the density and size of fish inside and outside of no-take zones (Wilson et al. 2010, Babcock and MacCall 2011, McGilliard et al. 2011), catch curve analyses (Wayte and Klaer 2010, Hordyk et al in press), and catch per unit effort (CPUE) (Little et al 2010). Importantly, most of the data limited methods in existence do not attempt to estimate biomass-based metrics or reference points.

Rather, these methods typically estimate metrics such as Spawning Potential Ratio (SPR), Yield per Recruit (YPR), and fishing mortality (F). Although data limited assessments rarely relate to biomass-based reference points, practical experience with many fisheries has resulted in robust alternatives; for example, maintaining SPR levels above 30-40% (depending on species) (Mace and Sissenwine 1993, Ralston 2002) and keeping F levels at some fraction of natural mortality (M) often result in long-term sustainable yields. If specific information is available on priority stocks (e.g., that a lobster population can sustain fishing mortality in excess of natural mortality), these reference points should reflect that knowledge.

Data limited assessments have been explored in the academic literature through the use of management strategy evaluation (MSE). Management strategy evaluation simulates a fish population, a fishery, a monitoring program, and a management decision-making process to explore probable outcomes from applying a specific set of monitoring and management actions over time (Butterworth et al 1999). Many data limited assessment approaches have shown to be effective in these simulation models and result in meeting target objectives for the hypothetical fishery. However, the outputs from most data limited assessments are more uncertain or biased than conventional statistical stock assessments models (Carruthers et al 2014). Recognizing and considering uncertainty and bias in assessment outputs is critical to making informed management decisions. Accounting for uncertainty and bias becomes even more important when attempting to manage multi-species and multi-gear fisheries, when borrowing information from similar species or nearby geographies, when data do not accurately represent a random sample of the population, or when equilibrium assumptions are violated, among others. As we will discuss in more detail within the framework description below, one way to reduce this uncertainty is to use a suite of data limited approaches concurrently to evaluate multiple performance indicators. Consistency among multiple indicators (especially when independent sources of data are used) increases confidence in the results.

Designing the adaptive management framework

It is important that the entire adaptive management process be participatory in order to: draw on the knowledge of scientists, resource users, government agencies, and others; create common goals and a common understanding of the fishery; and create a context for learning together and working cooperatively. This reduces uncertainty and conflict while increasing the likelihood of compliance with regulations generated by the adaptive management process. The steps for designing the adaptive management framework are shown in Figure 1 and are generally outlined as follows:

1. Define social, ecological, and economic goals

Outlining the goals of the fishery and community will inform the rest of the design process. For example, a community whose goals are primarily to maximize fisheries harvest every year will set very different reference points than a community interested in generating fishery yields while also increasing fish biomass in the water to support tourism.

2. Identify key target species for management

These species may have economic importance (high value or high volume species), special cultural or biodiversity value (such as endangered or keystone species), or may be particularly vulnerable or resilient. It is important to consider not only the species that are currently generating the most yield or revenue, but also species that may once have been important fisheries targets but are now depleted. Additional target species may have little commercial value but are important for other reasons. A suite of species may be chosen for management, and may be desirable for managing the complete ecosystem.

3. Identify species or ecosystem performance indicators (including indicators calculated using DLSAs)

Based on target species, identify appropriate performance indicators for each species. Performance indicators are data streams or model outputs that provide information about the current status of the population - they *indicate* how things are going. For example, examining trends over time in the ratio of observed fish density outside to inside a no-take zone marine reserve can provide insight into whether a stock is locally overfished, and if so, how overfished it might be. Other performance indicators include trends in CPUE, fishing mortality, SPR, local ecological knowledge, and many others (see Table 1). In order to calculate certain indicators, data limited stock assessment methods are often employed.

Table 1: Common performance indicators, data requirements, and example target and limit reference points. Many methods will require life history information (LHI).

Performance indicator	Data requirements	Single Species/Multi-Species/Ecosystem	Example target reference point	Example limit reference point
Total Landings	Catch data	Single/Multi/Ecosystem	Total Landings increasing	Total Landings decreasing rapidly
SPR	Fishery-dependent lengths, LHI	Single	SPR_{Tar}=30-40%	SPR_{Lim}=20%
F	Fishery-dependent lengths, LHI	Single	F_{Tar}=0.75M	F_{Lim}=2M
CPUE	Catch and effort data	Single/Multi	CPUE increasing	CPUE decreasing rapidly
Density	Fishery-independent surveys	Single/Multi/Ecosystem	D_{Tar}=800kg/Ha	D_{Lim}=500kg/HA
Outside/Inside MPA Density Ratio	Fishery-independent surveys	Single/Multi/Ecosystem	DR_{Tar}=0.4	DR_{Lim}=0.2 (single stocks) DR_{Lim}=0.3 (ecosystems)
Fraction Mature	Fishery-dependent lengths, LHI	Single	$Lmat_{Tar}$=90%	$Lmat_{Tar}$=50%
Fraction Megaspawner	Fishery-dependent lengths, LHI	Single	$Lmega_{Tar}$=20%	$Lmega_{Tar}$=30%

Each species should have several indicators, which should ideally be based on different data streams, in order to gain a more complete understanding of the fishery and reduce uncertainty. Additionally, ecosystem-level indicators should be included in the suite of indicators if the sustainable provision of non-fishery ecosystem services is a management goal. Looking across multiple indicators can spread the risk across data types and models, thus eliminating the potential for a single model to produce severely biased or error prone outputs. The indicators that are chosen will depend on what assessment techniques work well for a particular species, resources available for data collection, and technical capacity for analyzing data and performing data limited stocks assessments. The necessary technical capacity will depend on the indicator - analysis may range from examining simple trends in CPUE to more complex model-based calculations of SPR.

4. Develop data collection and management strategy to inform performance indicators

Each indicator will require certain data to calculate the indicator. Example data requirements for several indicators are given in Table 1. Standardized data collection protocols should be developed such that an appropriate level of statistical confidence can be associated with each indicator and such that biases are fully understood and accounted for. Many methods will require life history information (LHI). Data should be managed in a robust and secure manner, and ideally stored in a centralized and secure database.

5. Set reference points for each indicator

For each indicator, set target and/or limit reference points. A target reference point is a numerical value (or range of values) that indicates that the status of a stock is at a desirable level; often management is geared towards achieving or maintaining this target. A limit reference point is numerical value that indicates that the status of a stock is unacceptable (e.g. overfished), and that management action should be taken to improve stock status. Additionally, target or limit reference points can be defined as trends in a particular indicator (e.g. CPUE is increasing). While there are certain internationally recognized standards for appropriate reference points (e.g. SPR=30-40%), setting these points for a particular fishery will depend on social, ecological, and economic goals. Example reference points are given in Table 1.

6. Define harvest control rules

Using the suite of species and ecosystem indicators identified, define harvest controls rules that adjust harvest regulations based on a comparison of each of the current indicators relative to reference points. For each combination indicator/reference point comparison (e.g. SPR<target, F>target, and CPUE trend is decreasing), adaptive management participants should think through possible causes of this pattern and what management response should take place. Determining management decisions becomes considerably easier when multiple indicators suggest a common outcome. When the indicators suggest conflicting outcomes, it may be desired to exercise precautionary management actions or to increase monitoring of the resource. Management responses may include some combination of adjustments in effort, gear restrictions, size and sex-specific regulations, spatial or seasonal closures, and catch limits. Interpreting indicators and defining harvest control rules is a technical process and should include formal management strategy evaluation and consultation with fisheries scientists.

Using the adaptive management framework

With the framework designed, the generalized steps of implementing the adaptive management framework are given as follows. By repeating the process iteratively on a regular schedule, harvest regulations are adapted over time to move performance indicators closer to their reference points and move the fishery and community closer to their goals. Details regarding each of the following steps should be fully specified during the design phase of the framework.

1. Collect data to inform indicators
2. Analyze data to calculate indicators (including DLSA analysis)
3. Compare indicators to reference points using harvest control rules
4. Adjust harvest regulations accordingly
5. Repeat steps 1 – 4 on a specified periodic basis (typically annually)

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