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# An indicator-based adaptive management framework and its development for data-limited fisheries in Belize

Gavin McDonald[a,*,1], Bill Harford[b], Alejandro Arrivillaga[c], Elizabeth A. Babcock[b], Ramon Carcamo[d], James Foley[e], Rod Fujita[f], Todd Gedamke[g], Janet Gibson[h], Kendra Karr[f], Julie Robinson[i], Jono Wilson[j]

[a] Marine Science Institute and Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106, USA
[b] Rosenstiel School of Marine & Atmospheric Science, University of Miami, Miami, Florida 33149, US
[c] Rare, Guadalajara, México 44630, United States
[d] Belize Fisheries Department, Belize City, Belize
[e] Toledo Institute for Development and Environment, Punta Gorda, Belize
[f] Environmental Defense Fund, San Francisco, CA 94105, United States
[g] MER Consultants, Stuart, FL 34997, United States
[h] Wildlife Conservation Society, Belize City, Belize
[i] The Nature Conservancy, Belize City, Belize
[j] The Nature Conservancy and Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106, USA

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## ABSTRACT

Decisions regarding the selection and implementation of management strategies that constrain fishing pressure can be among the most difficult choices that fisheries managers and stakeholders must make. These types of decisions often need to be confronted in a data-limited context, where few if any management measures are currently in place or fisheries are managed independent of adequate scientific advice. This situation can sometimes create a high risk of overfishing and potential loss of economic and social benefits. To address this situation, simple model-free indicator-based frameworks have the potential to be effective decision-making platforms for fisheries where quantitative estimates of biomass and fishing mortality based reference points are lacking. In this paper, a multi-indicator framework is developed that enables decision-makers to proceed with management decisions in data-limited situations. Model-free indicators are calculated using trends in observed data, rather than stock assessment derived estimates of biomass and fishing mortality. The framework developed is adaptive so that adjustments to catch or effort are recursive and can respond to changing environments, socioeconomic conditions, and fishing practices. Using stakeholder-defined objectives as a foundation, indicators and reference points of fishery performance are chosen that can be evaluated easily by undertaking analyses of available data. Indicators from multiple data streams are used so that uncertainty in one indicator can be hedged through careful interpretation and corroboration of information from alternative indicators. During the adaptive management cycle, managers and stakeholders evaluate each indicator against the associated reference points to determine performance measures, interpret the results using scientific and local knowledge, and adjust fishery management tactics accordingly using pre-defined harvest control rules. The framework facilitates the interpretation of situations in which performance measures suggest divergent stock abundance or productivity levels. A case study is presented on this framework's development for conch and lobster fisheries of Belize.

* Corresponding author.
*E-mail addresses:* gmcdonald@bren.ucsb.edu (G. McDonald), wharford@rsmas.miami.edu (B. Harford), ebabcock@rsmas.miami.edu (A. Arrivillaga), aarrivillaga@rare.org (E.A. Babcock), ramalive@yahoo.com (R. Carcamo), jfoley@tidebelize.org (J. Foley), rfujita@edf.org (R. Fujita), kkarr@edf.org (T. Gedamke), todd@merconsultants.org (J. Gibson), jgibson@btl.net (K. Karr), jrobinson@tnc.org (J. Robinson), Jono_Wilson@tnc.org (J. Wilson).
[1] **Permanent Address:** Sustainable Fisheries Group, Bren School of Environmental Science & Management, 2400 Bren Hall, University of California, Santa Barbara CA 93106-5131.

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## 1. 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 decisions are made on the basis of quantitative statistical stock assessments that estimate the status of the resource relative to predefined target or limit reference points [39]. Reference points are often calculated in terms of biomass and fishing mortality rates that are expected to achieve maximum sustainable yield (MSY; [58]). However, perhaps over 80% of the global catch occurs in fisheries that lack the necessary data, resources, infrastructure, and/or expertise to use conventional statistical stock assessment models to quantify biomass levels and estimate maximum sustainable yield [16]. These fisheries, instead of being subject to scientifically informed management controls, are often managed with ineffective regulations that may result in poor social and economic outcomes for those dependent on fishing [16].

To address the need for assessment and management of data-limited fisheries, there has been growing interest in data-limited assessment methods [20]. A variety of data-limited assessment methods have been developed that use simple models to estimate stock status in relation to management reference points. These reference points can correspond to MSY or proxies for MSY, including the fishing mortality at which MSY is achieved, fishing mortality corresponding to natural mortality rates, spawning potential ratios, or other targets and limits for stock depletion [38,53,65,35]. For instance, these methods can rely on age and length data [28,3,34,35,61] or the density and size of fish inside and outside of no-take zones [41,4,61]. However, a wholesale reliance on data-limited model-based assessment methods can be problematic in many instances. Many model-based data-limited assessments have been shown to be effective in simulation studies at meeting management objectives, but can sometimes perform poorly when population modeling assumptions are not consistent with actual stock dynamics [13,62].

As an alternative to model-based approaches, model-free (empirical) indicators of stock dynamics and fishery characteristics can be used to control harvests in data- and resource-limited situations [7]. Model-free assessment approaches generally do not utilize quantitative stock assessments and do not estimate MSY-based reference points; rather, proxy indicators of perceived changes in stock status are used to recursively adjust catches or fishing effort depending on the patterns and trends in observed data. Such methods have been shown to be cost effective and responsive to typical environmental and biological dynamics of fisheries systems [48]. While using model-free indicators is an attractive interim solution for data-limited fisheries, there is the potential for both imprecision and inaccuracy in observed indicators, and therefore this approach may not be a long-term substitute for improved data collection and model-based assessment approaches that could be deemed worthwhile for supporting the achievement of management objectives for high-value fisheries. Using model-free indicators may however be particularly useful for managing multi-species tropical fisheries in which it is not feasible to collect the necessary data for each species to carry out conventional stock assessments. In the proposed indicator-based approach, harvest control rules (HCRs) are specified as pre-determined decision processes that use indicators in adjusting fishery management tactics, such as a total allowable catch (TAC). Such approaches require adaptive decision-making, or sequential adjustments to management tactics through time [2,32]. The use indicator approaches in fisheries management is intuitively simple, yet rarely described is the process of developing such an approach in the context of the coincident interactions that take place between managers, stakeholders, and scientists (although see examples in [19] and [19]; [48]). In addition, a recent effort was undertaken to develop HCRs using this approach for the Spiny Lobster fishery in California, USA ([11]). The framework outlined here is adapted from the process developed in California to meet the fishery management needs in Belize.

This paper describes an 11-step process for designing and implementing an adaptive management framework (AMF) that relies upon model-free indicators and HCRs that are used to adjust fishery management tactics. The term "indicator" is used to mean any measured variable that provides information about the fishery or the fish stock and can be used to infer how the fishery is performing when considered relative to a reference points. Some indicators (referred to as model-free indicators) may be calculated without the use of a model using direct summaries of the data, while other indicators (referred to as model-based indicators) may be outputs of model-based data-limited assessments that may require additional technical capacity to undertake and interpret. Using data from multiple fishery-dependent and fishery-independent data sources, this framework enables multiple indicators to be integrated into an adaptive HCR. The 11-step process describes how the AMF can be designed and implemented beginning with compilation of existing information, defining stakeholder-oriented objectives, and identifying key fisheries to be managed. Based on data availability, objectives, and focal fisheries, appropriate indicators and relative target and limit reference points are chosen that can be easily quantified. Finally, a process is specified to guide decisions, which uses HCRs to adjust fishery management tactics according to differences between current indicator values and those reflecting target and limit reference conditions. The 11-step process is developed using a case study from Belize, where AMFs have been proposed for two of the most economically important fisheries, the Caribbean spiny lobster, *Panulirus argus*, (Latreille 1804), and queen conch, *Lobatus gigas* (Linnaeus 1758).

## 2. Case study fishery overview

Belize has been a global leader in marine conservation, and the Belize Fisheries Department (BFD) is committed to using the best available science for the management of important fishery resources. To do so, BFD is developing and evaluating national AMFs for the nation's lobster and conch fisheries, as well as developing a system of territorial user rights fisheries (TURFs), called Managed Access in Belize [24]. This process is being supported by the Belize Science Team (henceforth referred to as the “Science Team”), a collaboration of managers and scientists from BFD and a number of partner organizations. The Science Team gathers and evaluates data, conducts data analyses, and provides advice on the AMF to BFD. BFD has the final say over the recommendations given by the Science Team, allowing for decisions to be made that are in accordance with policies and management plans of the government.

Caribbean spiny lobster (*Panulirus argus*) and queen conch (*Lobatus gigas*) are the two most economically important wild capture fisheries in Belize, with lobster exports being valued at $13.6 million Belizean Dollars in 2014 and conch exports being valued at $8.9 million Belize Dollars in 2014 [57]. Additionally, over 3,000 full- and part-time fishers are currently registered in Belize, of which over 90% participate in the lobster and conch fisheries [12]. The spiny lobster fishery consists of free diving, traps, and shades (“casitas”), and is currently regulated by a seasonal closure from mid-February to mid-June, a size limit of carapace length greater than 3 in. or tail weight greater than 4 ounces, and a ban on the use of SCUBA [28]. Meanwhile, the conch fishery occurs by free diving at depths typically less than 18 m and is currently regulated by a seasonal closure from July through September as well as a size limit on conch siphon length and meat weights. For both fisheries, conch and lobster fishing effort, in terms of boat-days, is typically highest at the beginning of each respective fishing season [6].

In order to continue generating benefits from these fisheries and increase them over time, the Science Team has recommended limiting access to the fishery and controlling TACs through scientifically based