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Enhancing tools for data-limited management strategy evaluation within the South Atlantic, Gulf of Mexico, and U.S. Caribbean: An introduction

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Introduction

The Southeast Fisheries Science Center's (SEFSC's) *Science Plan 2013-2018* acknowledges that severe data limitations persist despite high economic dependence on fisheries resources within the Southeast and U.S. Caribbean. In fact, less than half of the stocks for which the SEFSC is responsible for management of have scientifically rigorous management strategies because of data limitations (NOAA 2013). The SEFSC is responsible for assessing all stocks in the South Atlantic, Gulf of Mexico (GOM), and U.S. Caribbean regions, in addition to all Atlantic highly migratory species. As a major research focus, SEFSC's *Science Plan* stresses scientifically rigorous expansion of data collection to reduce scientific uncertainty and to improve the accuracy and precision of stock assessments (NOAA 2013).

Recent mandates in the U.S. for scientifically-derived annual catch limits (ACLs) have particularly challenged the stock assessment and management process in regions of the U.S. such as the Southeast and the Pacific (Berkson and Thorson 2015; Newman et al. 2015), where species biodiversity exceeds that of other marine ecosystems (e.g., Northeast US; Fautin et al. 2010). Since 2010, the setting of ACLs has been required for all U.S. managed stocks (see Newman et al. 2015 for a list of exceptions) and generally consists of a three step process (Fig. 1): (i) identify the annual catch when fishing the stock's current abundance at an estimate of the annual fishing mortality that corresponds to maximum sustainable yield (Overfishing limit, OFL; Carruthers et al. 2014; Punt et al. 2014); (ii) determine the catch level equivalent to or below the OFL that accounts for scientific uncertainty using a buffer against overfishing as prescribed by the most recent stock assessment (Acceptable Biological Catch, ABC; Carruthers et al. 2014; Newman et al. 2015); and (iii) establish the catch level equivalent to or below the ABC which accounts for various ecological, social, and economic factors in addition to uncertainty in management controls (Annual Catch Limit, ACL; Methot 2009; Carruthers et al. 2014; Newman et al. 2015).

The ability to set ACLs differs among species and across regions due to the quantity and quality of data. “Data-moderate” or “data-rich” stocks possess basic information on catch, relative abundance and biology to which conventional fisheries stock assessments can be applied (Carruthers et al. 2014; Newman et al. 2015). Nearly 60% of fish stocks managed in the U.S. are considered “data-poor” (Newman et al. 2015) in that they lack the necessary information (e.g., abundance index) to quantify current or historical stock status. The lack of reliable catch and abundance time series for the majority of stocks assessed by the SEFSC highlights the severity of data limitations in this region. Simple length-based indicators calculated from only recent years of length frequency data could be most appropriate (Froese 2004; Ault et al. 2005; Cope and Punt 2009; Babcock et al. 2013).

Relating this to the current stock assessment planned for the U.S. Caribbean (SEDAR 46), the U.S. Caribbean represents one of the most difficult areas to address the required guidelines for setting ACLs (Newman et al. 2015). Currently, OFLs/ABCs are computed using data-poor techniques for stock complexes, which are comprised of multiple stocks assumed to exhibit similar life history and exploitation levels (e.g., shallow-water groupers) (Newman et al. 2015). The ability to conduct stock assessments in the U.S. Caribbean region is hindered by insufficient data collections, such as having only short time series of catch records (which are often recognized as extremely uncertain) and length-composition data (Cummings et al. 2014). Data collection is problematic in the Southeast U.S. because of the size and diversity of the resource area, costs of conducting survey operations, biases associated with sampling gear, complexities in life history patterns of marine organisms, and difficulties in sampling habitats that are inaccessible to conventional sampling gear such as trawls (Cummings et al. 2014).

Ongoing research, funded through a NOAA Fisheries Stock Assessment Analytical Methods (SAAM) grant, is aimed at identifying effective combinations of data-poor assessment methods and harvest control rules through simulated management strategy evaluation. This research is specifically intended to address severe data limitations as experienced in the Southeast and U.S. Caribbean. We employ management strategy evaluation (MSE), which is a scientifically robust approach that simulates the entire management system (Hertz and Thomas 1983; Sainsbury et al. 2000; Butterworth et al. 2010; Punt et al. 2014). While data-limited assessment methods that require catch histories and/or abundance time series have been examined using MSE (Wetzel and Punt 2011; Carruthers et al. 2014), simple length-based indicators (used when neither catch nor abundance data are available) have not received the same level of scrutiny. Length-based management strategies could prove useful to managers in a number of ways. For example, length-based approaches may advise on *interim* management strategies for coping with data limitations, until data collection can be improved. The SEFSC's *Science Plan* stresses expanded data collection to reduce scientific uncertainty and to improve stock assessments (NOAA 2013). To meet these goals, length-based approaches may be useful as they tend to be much less costly in terms of data collection. Thus, these methods may be appealing when managing fisheries where long-term data collection is impractical, including fisheries of low economic value. Thus, if length-based approaches can be made as robust as other approaches, they could be invaluable to federal and state fisheries managers in the Southeast and U.S. Caribbean.

Objective

The underlying objective of this study is to evaluate the feasibility of identifying harvest control rules that can link length-based assessment inputs to the specification of ACLs for fishery stocks assessed by the Gulf & Caribbean Branch of the SEFSC. Towards this objective, we will tailor the Stock Synthesis MSE procedure (Maunder 2014) to life histories of fishery stocks managed by Fishery Management Councils in the Southeast and U.S. Caribbean.

Approach

MSE Framework

One use of MSE (Fig. 2) is to identify the management option(s) that is (are) most robust to errors and uncertainties in data inputs (e.g., natural mortality) and to evaluate trade-offs between alternative management strategies (Kell et al. 2007; Ohshimo and Naya 2014; Punt et al. 2014). MSE is a cyclical step-by-step process (Fig. 2; Table 1) that consists of capturing system dynamics assumed to represent the truth in an operating model (OM) and "observed" system dynamics via simulation of (i) biological sampling, (ii) scientific analysis such as conventional fisheries stock assessment, and (iii) harvest control rules or management implementation (Sainsbury et al. 2000; Kell et al. 2007). A harvest control rule is a predetermined decision process that connects information about the population assessment to fishery management tactics (Fig. 1) (Sainsbury et al. 2000; Harford 2014). Because stock dynamics and management strategies are simulated together, MSE emphasizes the collective performance of monitoring, analysis, and decision-making (Sainsbury et al. 2000; Kell et al. 2007; Carruthers et al. 2014). A feedback loop between the management strategy and operating model ensures the linkage of observed system dynamics to true system dynamics (Kell et al. 2007), which helps to distinguish MSE from simple risk assessment (Punt et al. 2014).

Management objectives and performance criteria

Management objectives based on the Caribbean Fishery Management Council's Fishery Management Plan for shallow-water reef fish are given in Table 2 (CFMC 1985; CFMC 1993). Other potential management objectives could be to promote the efficiency and profitability of the fishery or could include stabilizing the catch, reducing discards, and encouraging cooperative interstate management (Punt et al. 2014). Harvest control rule performance will be evaluated in terms of whether management objectives are likely to be achieved. Potential performance metrics include the probabilities of preventing overfishing and overfished status and how well National Standard Guidelines can be achieved. Additional performance metrics for consideration are listed in Table 3.

Operating model

Within an MSE, the operating model represents the biological components of the system to be managed, fisher behavior in response to management actions, how data are collected from the management system, and environmental conditions as well as interactions (Kell et al. 2007; Carruthers et al. 2014; Maunder 2014; Ohshimo and Naya 2014; Punt et al. 2014). For the purpose of this study, we will develop an operating model based on red grouper (*Epinephelus morio*) life history, fishery dynamics and expert opinion from the 2015 Gulf of Mexico red grouper benchmark stock assessment (SEDAR 42) using Stock Synthesis (Methot and Wetzel 2013). This approach assumes that the current red grouper assessment describes true system dynamics almost perfectly (Kell et al. 2007). Stock Synthesis is an integrated assessment modeling framework that incorporates multiple sources of data (Fig. 3) to provide a more comprehensive picture of abundance and impacts of fishing on stock dynamics (Methot and Wetzel, 2013). This software is broadly applicable (Punt et al. 2014) and enables simulation of alternative parameter values and model structures such as variability in stock-recruitment steepness, depletion, natural mortality, and the magnitude of sampling error (Maunder 2014).

Management Strategies

A suite of length-based assessment approaches will be tested within our implementation model (Table 4). Length-based metrics characterize aspects of stock demography which in turn reflect changes in stock size through time (Ault et al. 2005; Cope and Punt 2009; Geromont and Butterworth 2014b).

Relevance to the U.S. Caribbean SEDAR 46 stock assessment evaluation

Evaluation of potential management strategies should precede implementation in the real world because these strategies may not be robust to a wide range of uncertainties. Therefore, MSE can be used to test the robustness of a management strategy over a wide range of uncertainties (Kell et al. 2007; Maunder 2014; Ohshimo and Naya 2014). For instance, preference could be given to management strategies that are robust to uncertainties that emerge from data limitations. Alternatively, by exposing where management strategies are not robust, MSE can elucidate data needs and guide improvements to the management process (Olsen et al. 1999; Walters and Martell 2004; Magnusson and Hilborn 2007; Harford 2014; Punt et al. 2014).

Using length-based assessment to inform U.S. fisheries management poses an additional challenge because these approaches do not calculate current stock abundance, on which ACLs are typically based. Translating length-based metrics into quantitative and transparent control rules for catch adjustment requires a detailed examination using MSE (Cope and Punt 2009). Thus, formulation of harvest control rules will be guided by (i) conceptual linkages between length-based metrics and stock status and by (ii) National Standard Guidelines for setting ACLs. We thus expect that SEDAR 46 could serve as an invaluable source of information about the pragmatism associated with conducting data-poor assessments. Consequently, the subsequent steps of defining harvest control rules, and linking these rules with stock assessment results, will build upon assessment processes carried out during SEDAR 46.

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Table 1. Step-by-step procedure for conducting a management strategy evaluation, as adapted from Punt et al. (2014).

		Involvement in MSE process			
Step	MSE Procedure	Analyst	Decision-makers	Stakeholders	NGOs
1	Identify management objectives and performance statistics to quantify them	X	X	X	X
2	Identify a broad range of uncertainties	X	X	X	X
3	Develop a set of models: Operating model - describes plausible states of nature by specifying parameters and quantifying parameter uncertainty using Bayesian posterior distributions or bootstrapping Implementation model - describes how management regulations and harvest control rules are applied in practice	X	X	X	X
4	Identify candidate management strategies for implementation	X	X	X	X
5	Simulate the application of each management strategy for each operating model	X			
6	Summarize and interpret the performance statistics (set in step 1)	X			

Table 2. Management objectives based on the Fishery Management Plan for the Shallow-water Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands.

Management objectives
Caribbean Fishery Management Council (CFMC 1985; CFMC 1993)
1. Obtain the necessary data for management and monitoring
2A. Reverse the declining trends in the resource: restore and maintain adult stocks at levels that ensure adequate spawning and recruitment to replenish the population
2B. Reverse the declining trends in the resource: prevent the harvest of individuals of species of high value (e.g., snappers, groupers, and others) that are less than the optimum size
3. Reduce the opportunity for conflicts among harvesters of the resource
4. Promote compatible, if not uniform, management of the pan-Caribbean species in the unit
5. Improve stock conditions
6. Maintain stocks at optimal levels for maximum harvests
7. Provide for the management of depleted deep-water reef fish resources (Amendment 2)
8. Provide for the management of species entering the aquarium trade (Amendment 2)

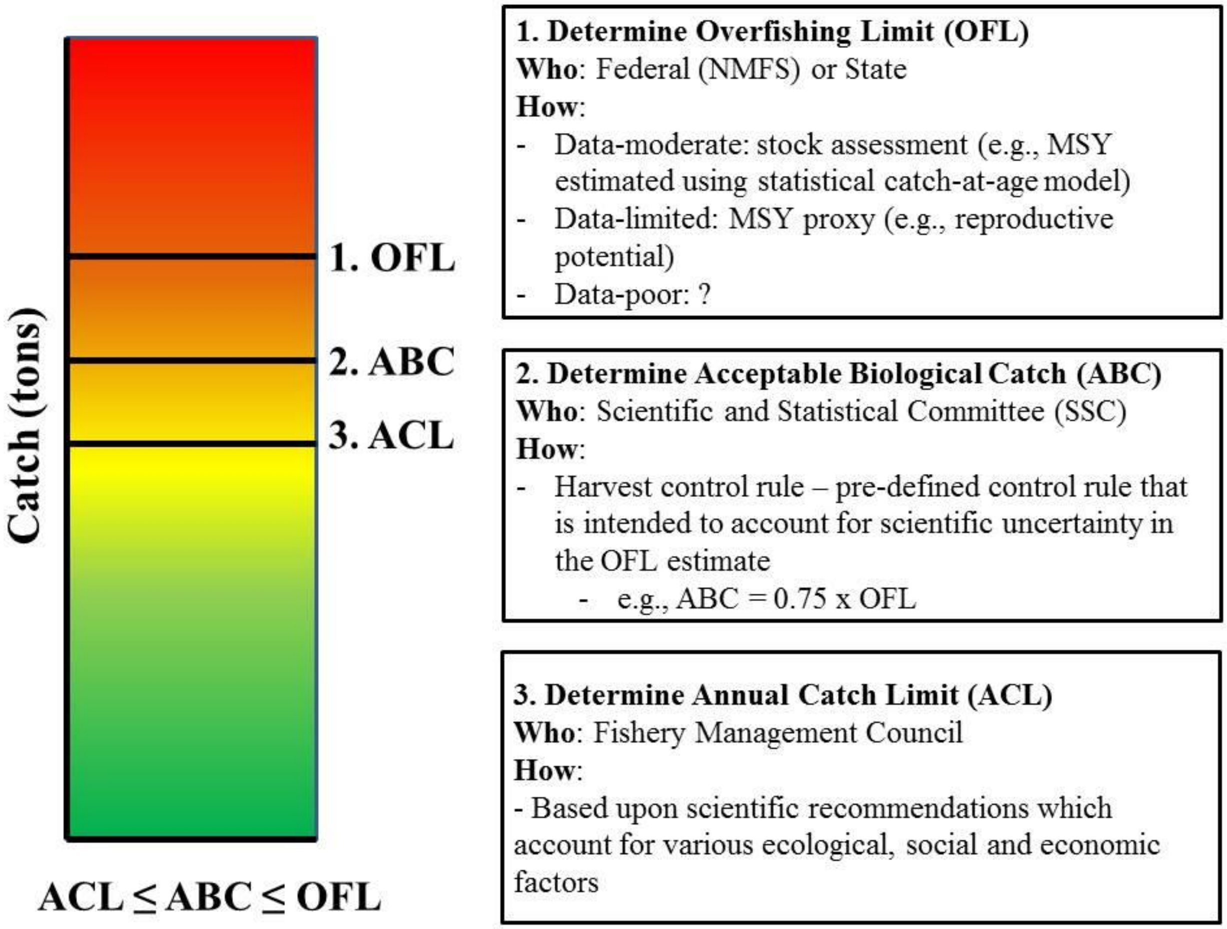
Table 3. Performance metrics used in management strategy evaluation.

Performance metric	Reference
Stock size	
Spawning Stock Biomass (SSB)	Carruthers et al. (in press); Geromont and Butterworth (2014b)
Long-term SSB	Carruthers et al. (in press)
Frequency of stock collapse	Ohshimo and Naya (2014)
Mean stock size	Ohshimo and Naya (2014)
Overfished stock status	Carruthers et al. (2014)
Probability of biomass increasing	Carruthers et al. (2014)
Ratio of final spawning biomass at the end of the projection period to the final spawning biomass as estimated by the original assessment (Btarget)	Geromont and Butterworth (2014a); Geromont and Butterworth (2014b)
Ratio of minimum spawning biomass over the projection period to Btarget	Geromont and Butterworth (2014a)
Exploitation	
Fishing mortality rate (F)	Carruthers et al. (in press); Geromont and Butterworth (2014a)
Probability of overfishing	Carruthers et al. (2014)
Final spawning biomass depletion	Geromont and Butterworth (2014b)
Harvest	
Relative yield	Carruthers et al. (2014); Carruthers et al. (in press)
Mean catch	Ohshimo and Naya (2014); Geromont and Butterworth (2014a); Geromont and Butterworth (2014b)
Variability	
Average annual variability in yield or catch	Carruthers et al. (in press); Geromont and Butterworth (2014a); Geromont and Butterworth (2014b)
Average annual variation in F	Geromont and Butterworth (2014a)
Coefficient of variation (CV) of stock size during management period	Ohshimo and Naya (2014)
CV of catch during management period	Ohshimo and Naya (2014)
Other	
Frequency of management failure	Ohshimo and Naya (2014)

Table 4. Length-based assessment metrics to be linked to harvest control rules.

Reference	Length-based metric	Overfishing limit
Froese (2004); Cope and Punt (2009)	Pmat Popt Pmega	Pobj
Ault et al. (2005)	Spawning potential ratio	40% SPR
O'Farrell and Botsford (2005)	Lifetime egg production	50% LEP

Figure 1. Procedure for setting annual catch limits (ACLs), adapted from the National Standard 1 Guidelines.



1. Determine Overfishing Limit (OFL)
Who: Federal (NMFS) or State
How:
- Data-moderate: stock assessment (e.g., MSY estimated using statistical catch-at-age model)
- Data-limited: MSY proxy (e.g., reproductive potential)
- Data-poor: ?

2. Determine Acceptable Biological Catch (ABC)
Who: Scientific and Statistical Committee (SSC)
How:
- Harvest control rule – pre-defined control rule that is intended to account for scientific uncertainty in the OFL estimate
  - e.g., ABC = 0.75 x OFL

3. Determine Annual Catch Limit (ACL)
Who: Fishery Management Council
How:
- Based upon scientific recommendations which account for various ecological, social and economic factors

Figure 2. Management strategy evaluation framework. Grouper image obtained from www.fishwater.gov, *Karenia brevis* and fishing vessel images obtained from https://en.wikipedia.org/wiki/.

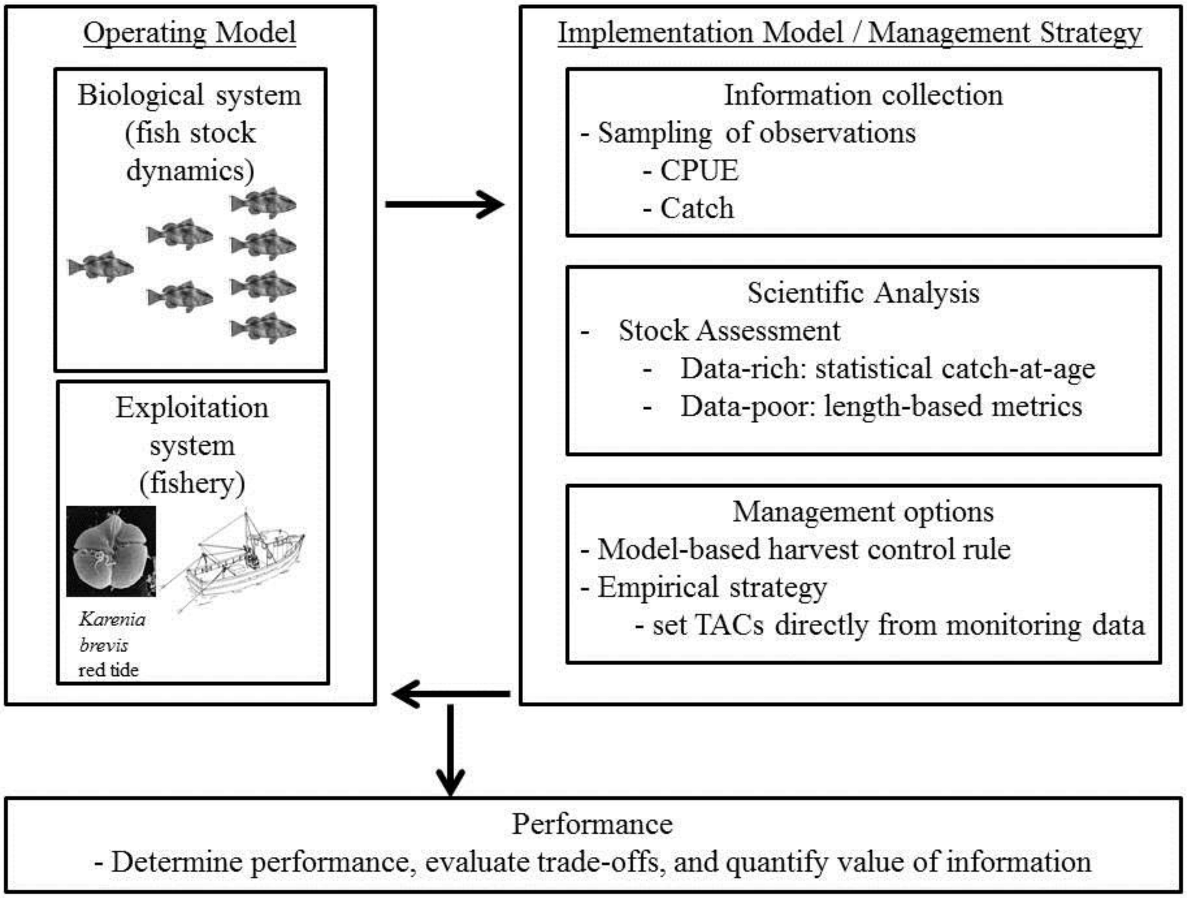


Figure 3. Summary of data inputs for the 2015 Gulf of Mexico red grouper benchmark stock assessment (SEDAR 42) conducted using Stock Synthesis. Fishery-dependent data sources include commercial vertical line (commHL), commercial longline (commLL), commercial trap (commTrap), recreational charterboat and private (CBT_PR), and recreational headboat (HB). Fishery-independent data sources include combined video survey (SEAMAP_Vid), SEAMAP groundfish survey (SEAMAP_GF), and NMFS bottom longline survey (NMFS_BLL). RedTide refers to a pseudo-fishing fleet indexing removals of red grouper due to red tide mortality. Catch units are in biomass (metric tons) and numbers (1000s of fish) for commercial and recreational data sources, respectively. All discards are in numbers.