Fisheries Research 190 (2017) 84–94

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Interim and long-term performance of static and adaptive management procedures

William J. Harford[a,*], Thomas R. Carruthers[b]

[a] Cooperative Institute for Marine and Atmospheric Studies, Rosenstiel School of Marine & Atmospheric Science, University of Miami, Miami, FL, 33149, USA
[b] Fisheries Centre, AERL, 2202 Main Mall, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada

ARTICLE INFO

Article history:
Received 1 September 2016
Received in revised form 6 February 2017
Accepted 7 February 2017
Handled by A.E. Punt
Available online 14 February 2017

Keywords:
Management strategy evaluation
Harvest strategy
Simulation
Fisheries management
Data-poor
Data-limited

ABSTRACT

Static and adaptive management procedures (MPs) based on contemporary data-poor approaches were tested by management strategy evaluation to reveal short- and long-term performance trade-offs. Short-term (10 year) and long-term (60 year) performance was evaluated for MPs such as Depletion-Corrected Average Catch, Depletion-Based Stock Reduction Analysis, and catch-MSY, and also for historical catch scalars. Static MPs established a catch limit at the outset of a projection time period and were not modified thereafter, which reflected their use as interim measures while data collection is improved. Conversely, adaptive MPs recursively adjusted catch limits, which reflected their longer-term use where data-poor circumstances are unlikely to improve. On average, adaptive MPs provided comparable performance over the short term, but had superior performance over the long-term and when stocks were considered moderately to heavily depleted. Our results highlight depletion as a critical quantity in establishing sustainable catches from historical catch observations. We reconfirm that depletion-based MPs are improvements over catch scalar methods that are widely used in US data-poor circumstances and we examine the value in obtaining updated depletion estimates to improve catch sustainability in data-poor circumstances.

1. Introduction

The 2006 amendment to the US Magnuson-Stevens Fishery Conservation and Management Act requires annual catch limits (ACLs) to prevent overfishing for most federally managed fish stocks (NOAA, 2007). This requirement includes many data-poor stocks, where data are insufficient to conduct a conventional stock assessment. Accordingly, ACL calculations for data-poor US fisheries have typically relied on catch histories and depletion (i.e., biomass relative to unfished) as the principal data sources (Newman et al., 2015). Most of these Management Procedures (MPs[1]) use scalars of recent catches or expert judgment of stock depletion, e.g., Depletion-Corrected Average Catch (DCAC) and Depletion-Based Stock Reduction Analysis (DBSRA) (Dick and MacCall, 2011; MacCall, 2009; Newman et al., 2015). Depletion information is used to calculate ACLs in some data-poor Pacific groundfish fisheries and MPs that use depletion are being considered by the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils (Newman et al., 2014, 2015; SEDAR, 2015, 2016). Data-poor MPs such as DCAC and DBSRA can be seen as interim measures while data collection is improved, rather than as longer-term management approaches. However, the interim nature of some data-poor MPs may not be suitable in instances where low revenues from data-poor stocks are unlikely to support improvements in data collection (Newman et al., 2015; NOAA, 2007). Further, longer-term use of data poor MPs will be necessary when data streams that support quantitative stock assessment are unavailable or are just starting to be collected. Thus, evaluating the interim and long-term performance of alternative data-poor MPs can contextualize MP design for a variety of management circumstances. In the US Caribbean, for instance, there is high economic dependence on fisheries, despite a current lack of scientifically rigorous MPs for more than half of their exploited stocks (Anon, 2013).

We evaluate static and adaptive MPs that each start with an estimate of current stock depletion. In a real data-poor setting this initial depletion estimate may be derived from a range of approaches including current fishery length-composition data (e.g., Thorson and Cope, 2015), expert judgement (e.g., using Productivity Susceptibility Analysis, PSA, Cope et al., 2015) or inference from concomitant data-rich stocks ("Robin Hood" approaches, Punt

* Corresponding author.
E-mail address: william.harford@noaa.gov (W.J. Harford).

[1] A fishery MP is an algorithm that may encompass (i) information collection, (ii) data analysis that can include stock assessment, and (iii) decision-making based upon a harvest control rule (Butterworth, 2007; Butterworth and Punt, 1999; Geromont and Butterworth, 2015; Punt et al., 2016; Sainsbury et al., 2000).

http://dx.doi.org/10.1016/j.fishres.2017.02.003
0165-7836/

et al., 2011). Static management uses this initial estimate of depletion just once to make a management recommendation that is maintained in the future. Adaptive MPs start with the same initial depletion estimate but then provide variable future management recommendations based on updated relative abundance information inferred from, for example, a fishery-independent survey (Gunderson, 1993; Smith, 1990), fishery catch-rate data (Maunder et al., 2006; Maunder and Punt, 2004), or size-composition data (Klaer et al., 2012). A principal aim of this analysis is to quantify the potential value of collecting and processing current data to update an initial estimate of stock depletion.

We simulated performance of MPs that incorporated alternative methods for sustainable catch estimation, including DCAC, DBSRA, and the catch-MSY approach of Martell and Froese (2012). Performance testing involved simulating the outcomes of the dynamic linkages between a fish stock, its fisheries, and a MP. This simulation approach is known as management strategy evaluation (Butterworth and Punt, 1999; Punt et al., 2016). Recognizing that analytical methods such as DCAC are typically developed to support interim management actions, we evaluated the performance of static and adaptive MPs over both short-term (10 year) and long-term (60 year) time horizons. Short-term performance evaluation was aimed at guiding selection of interim management procedures. However, even where interim solutions are sought, short-term performance alone may not reveal whether an MP pathologically overfishes, whereas long-term performance may be a better indicator of sustainable MP behavior. It follows that short-term performance is often not considered without also considering longer term outcomes. Long-term performance evaluation is also clearly important when data limitations are likely to persist into the foreseeable future and can reveal the potential value in the adaptive updating of initial data inputs to MPs.

2. Methods

Management strategy evaluation as it is applied in this paper, provides guidance on appropriate MPs, their expected performance, appropriate time-horizons for their use and the value of various data, forming the basis of a more transparent and rigorous decision-making framework (Geromont and Butterworth, 2015; Newman et al., 2014). Nine MPs were developed based on DCAC, DBSRA, the catch-MSY approach (SPMSY), and mean historical catches (MC) (Table 1). Two types of harvest control rule were investigated: static control rules that specified an annual Total Allowable Catch (TAC) at the outset of the projection period and maintained this TAC thereafter (denoted by "_s" in naming), and adaptive control rules that modified TACs periodically during the projection period (denoted by "_adj" in naming, as in adjusted MPs). Thus, adaptive MPs were constrained to differ from their static MP counterparts only with respect to the updating of depletion information used in recursive TAC setting. These two classes of control rule enabled a comparison of static MPs, perhaps intended for interim use, with adaptive MPs that could be subsequently implemented (or transitioned to) in the longer-term given updated information about stock depletion.

Simulations were carried out in the R computational environment using the Data Limited Methods toolkit package (Carruthers and Hordyk, 2016; DLMtool v3.2; R Development Core Team, 2012). We specified six operating models that were a factorial combination of three levels of stocks representing Pacific herring (*Clupea pallasii*), western Atlantic bluefin tuna (*Thunnus thynnus*), and canary rockfish (*Sebastes pinniger*), and two levels of initial stock depletion: vulnerable biomass in the range of 5–20% of unfished ("More depleted") and 20–60% of unfished ("Less depleted"). For each of the six operating models, the nine MPs were tested subject to two observation error models (precise-unbiased and imprecise-biased). In each case, 500 simulations were carried out, which was

Table 1
Data inputs for management procedures. These inputs are: historical catch time series C_{series}, mean historical catch C_{Ave}, natural mortality M, the ratio of fishing mortality rate at maximum sustainable yield to the natural mortality rate F_{MSY}/M, biomass at maximum sustainable yield *Bpeak*, depletion at the end of the historical time period D_n, annual depletion during year y of the projection time period D_y, age at 50% maturity A_{mat}, and resilience classification (*resilience*, see (Martell and Froese, 2012)).

MP name	Description	Catch-based reference point	Parameters for reference point estimation	Additional parameters for TAC calculation
DCAC_s	Static version of depletion corrected average catch (MacCall 2009)	DCAC	D_n, F_{MSY}/M, M, C_{Ave}, *Bpeak*,	None
DCAC2_s	Static version of modified depletion corrected average catch	DCAC	D_n, F_{MSY}/M, M, C_{Ave}, *Bpeak*,	None
DCAC2_adj	Adaptive version of modified depletion corrected average catch	DCAC	D_n, F_{MSY}/M, M, C_{Ave}, *Bpeak*,	D_y
DBSRA_s	Static version of depletion-based stock reduction analysis (Dick and MacCall 2011)	MSY	D_n, F_{MSY}/M, M, C_{series}, *Bpeak*, A_{mat}	None
DBSRA_adj	Adaptive version of depletion-based stock reduction analysis	MSY	D_n, F_{MSY}/M, M, C_{series}, *Bpeak*, A_{mat}	D_y
SPMSY_s	Static version of catch-MSY approach (Martell and Froese 2012)	MSY	C_{series}, *resilience*	D_n
SPMSY_adj	Adaptive version of catch-MSY approach	MSY	C_{series}, *resilience*	D_y
MC_s	Static mean catch using last 20 years of historical time period	Mean historical catch	C_{series}	None
MC_adj	Adaptive version of mean catch using last 20 years of historical time period and depletion adjustment	Mean historical catch	C_{series}	D_y