Fisheries Research 193 (2017) 60–70

Contents lists available at ScienceDirect

Fisheries Research

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

Full length article

The refined ORCS approach: A catch-based method for estimating stock status and catch limits for data-poor fish stocks

Christopher M. Free[a,*], Olaf P. Jensen[a], John Wiedenmann[b], Jonathan J. Deroba[c]

[a] Department of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ, USA
[b] Department of Ecology, Evolution, and Natural Resources, Rutgers University, New Brunswick, NJ, USA
[c] NOAA Fisheries, Northeast Fisheries Science Center, Woods Hole, MA, USA

ARTICLE INFO

Article history:
Received 14 December 2016
Received in revised form 24 March 2017
Accepted 25 March 2017
Handled by A.E. Punt
Available online 17 April 2017

Keywords:
Stock assessment
Data-limited fisheries
Only reliable catch stocks
Catch-only methods
RAM Legacy Stock Assessment Database

ABSTRACT

The 'Only Reliable Catch Stocks' (ORCS) Working Group approach to data-poor fisheries stock status and catch limit estimation has been used by U.S. fisheries managers but has yet to be fully evaluated. The ORCS approach estimates stock status using a fourteen question 'Table of Attributes' and the overfishing limit by multiplying a historical catch statistic by a scalar based on the estimated status. We evaluated the performance of the approach by applying it to 193 stocks with data-rich stock assessments and comparing its predictions of stock status with the assessment model estimates. The approach classified all but three stocks as fully exploited indicating that it is a poor predictor of status and should not be used by managers. We refined the original ORCS approach by: (1) developing a more predictive model of stock status using boosted classification trees and (2) identifying the historical catch statistics and scalars that best estimate overfishing limits using assessment model data. The refined ORCS approach correctly classified 74% of all stocks and 62% of overexploited stocks in a training dataset and 74% of all stocks and 50% of overexploited stocks in an independent test dataset. The refined approach performed better than six other widely used catch-only methods. However, the overfishing limits estimated by the refined approach would further deplete overexploited stocks without the use of conservative catch scalars to buffer against classification uncertainty. Conservative catch scalars can reduce the probability of overfishing below 50%, the U.S. legal maximum, but with concomitant increases in the probability and magnitude of underfishing. The refined ORCS approach may therefore be useful when other methods are not possible or appropriate and some risk of underfishing is acceptable.

1. Introduction

The majority of global fish stocks lack adequate data for estimating sustainable fishing levels using conventional stock assessment methods. In developing countries, only 5–20% of fish stocks are assessed and this fraction increases to only 10–50% in developed countries (Costello et al., 2012). In the United States, 30% of stocks are managed using conventional 'data-rich' assessment methods, while the remaining 11% and 59% of stocks are managed using 'data-moderate' and 'data-poor' methods, respectively (Newman et al., 2015). Data-rich stock assessment methods combine (1) total catch; (2) an index of relative abundance; and (3) other biological information to assess stock status and estimate sustainable fishing levels (Walters and Martell, 2004). Data-poor and data-moderate methods generally utilize only one and two of these data types, respectively, with total catch information often being the only data type available. Thus, data-poor methods are often synonymous with catch-only methods.

In 2006, the U.S. Magnuson-Stevens Fishery Conservation and Management Act was amended to require scientifically-derived annual catch limits (ACLs) that prevent overfishing for all federally managed fish stocks, including data-limited stocks (DOC, 2007). This mandate stimulated the revival of old data-limited methods (Gulland, 1971; Restrepo et al., 1998), development of new data-limited methods (MacCall, 2009; Dick and MacCall, 2011; Cope, 2013; Cope et al., 2013), and evaluation of the relative performance of these methods (Wetzel and Punt, 2015; Wiedenmann et al., 2013; Carruthers et al., 2014). In 2011, the 'Only Reliable Catch Stocks' (ORCS) Working Group (Berkson et al., 2011) convened to evaluate catch-only methods for ACL estimation and recom-

Abbreviations: ORCS, only reliable catch stocks; TOA, table of attributes; RAMLDB, RAM Legacy Stock Assessment Database; BCT, boosted classification trees.

* Corresponding author at: Department of Marine and Coastal Sciences, Rutgers University, 71 Dudley Road, New Brunswick, NJ 08901, USA.
E-mail address: cfree@marine.rutgers.edu (C.M. Free).

http://dx.doi.org/10.1016/j.fishres.2017.03.017
0165-7836/

Table 1
ORCS Table of Attributes. (TOA; adapted from SAFMC, 2012).

#	Attribute	Stock status[a]		
		Underexploited (1)	Fully exploited (2)	Overexploited (3)
1	Status of assessed stocks in fishery[b]	<10% overfished	10–25% overfished	>25% overfished
2	Refuge availability *(not used in refined approach)*	<50% of habitat accessible	50–75% of habitat accessible	>75% of habitat accessible
3	Behavior affecting capture	----------	No aggregation behavior	Exhibits aggregation behavior
4	Morphology affecting capture *(not used in refined approach)*	Low susceptibility	Average susceptibility	High susceptibility
5	Discard rate[b]	Discards <10% of catch	Discards 10–25% of catch	Discards >25% of catch
6	Targeting intensity	Not targeted	Occasionally targeted	Actively targeted
7	M compared to dominant species[c]	Higher mortality rate	Equivalent mortality rates	Lower mortality rate
8	Occurrence in catch	Sporadic *(in <10% of efforts)*	Common *(in 10–25% of efforts)*	Frequent *(in >25% of efforts)*
9	Value (US$/lb, 5-year mean) *(continuous value in refined approach)*	<$1/lb	$1-$2.25/lb	>$2.25/lb
10	Recent trend in catch	Increasing last 5 years *(score=1.5 in original approach)*	Stable last 5 years *(score=1.5 in original approach)*	Decreasing last 5 years
11	Habitat loss[d]	No time in threatened habitats	Part time in threatened habitats *(full time in partially threatened habitats)*	Full time in threatened habitats
12	Recent trend in effort	Decreasing last 5 years	Stable last 5 years	Increasing last 5 years
13	Recent trend in abundance index	Increasing last 5 years	Stable last 5 years	Decreasing last 5 years
14	Proportion of population protected	Most of resource is protected *(size limits AND time/space closures)*	Some of resource is protected *(size limits OR time/space closures)*	None of resource is protected *(no size limits or time/space closures)*

[a] In the original ORCS approach, stock status is estimated as the mean of the TOA scores (<1.5=underexploited; 1.5–2.5=fully exploited; >2.5=overexploited).
[b] Replaced vague score descriptions in the original table with straightforward percentage thresholds. Note: the definition of overfishing varies by management agency (Supplementary Appendix A.2).
[c] Removed ambiguity of score descriptions in the original table and specified that M's must differ by >20% to be considered different. See Supplementary Appendix A.2 for definition of dominant species.
[d] Rephrased original attribute to be conceptually simpler and easier to score. See Supplementary Appendix A.2 for list of threatened habitats.

mended the following hierarchy for determining ACLs for ORCS: (1) depletion-based stock reduction analysis (DB-SRA; Dick and MacCall, 2011) when a complete time series of annual catches is available (i.e., from the start of fishing to the present); (2) depletion-corrected average catch (DCAC; MacCall, 2009) when the stock exhibits low natural mortality rates ($\leq$0.20 yr^{-1}); and (3) the new ORCS Working Group approach (hereafter called the 'ORCS approach') when neither DB-SRA or DCAC are possible or appropriate (Berkson et al., 2011; later modified by SAFMC, 2012, 2013).

The ORCS approach was designed to provide an ecological basis for the Restrepo et al. (1998) scalar approach. In both methods, the overfishing limit (OFL; the catch at F_{MSY}) is calculated by multiplying an expert-defined historical catch statistic (e.g., mean catch over the previous 10 years or median catch over the whole time series) by a scalar also based on expert judgment. In the ORCS approach, the choice of scalar is determined by stock status (i.e., under, fully, or overexploited), which is estimated as the mean score of fourteen stock- and fishery-related attributes (the 'Table of Attributes' or TOA; Table 1). The ORCS approach allows for considerable flexibility in its implementation, as scientists and managers can exercise expert judgement to: (1) estimate status using an arithmetic, geometric, or weighted mean of the Table of Attributes scores; (2) modify the Table of Attributes' estimate of status or the thresholds used to delineate status; and/or (3) choose appropriate catch statistics and scalars. While this flexibility and reliance on expert judgement could improve performance, it is necessary to adopt a more specific, albeit less inclusive, definition of the ORCS approach to validate the method and demonstrate its transferability.

The ORCS approach is widely applicable, but the ability of the Table of Attributes to correctly predict stock status has not been evaluated and the performance of only a limited range of potential catch statistics and scalars has been tested. In the only explicit evaluation of the ORCS approach to date, Wiedenmann et al. (2013) used management strategy evaluation to show that the default scalars used to estimate the OFL are too conservative for under (scalar=0.5) and fully (scalar=1.0) exploited stocks and too generous for overexploited (scalar=2.0) stocks when stock status is correctly classified. They also show that catch limits are unsustainable when stocks are incorrectly classified into less-depleted categories (e.g., an overexploited stock incorrectly classified as fully exploited). Evaluations of scalar-based methods similar to the ORCS approach have also been shown to result in overfishing, especially for already depleted stocks and stocks whose statuses have been incorrectly classified (Carruthers et al., 2014; ICES, 2014, 2015, 2017). The sensitivity of management outcomes to status classification decisions makes the validation and refinement of the ORCS Table of Attributes' ability to estimate status necessary before the ORCS approach can be used to set catch-limits more widely.

The goals of the present study are to evaluate and refine the ORCS approach to data-poor catch limit estimation using stocks with data-rich stock assessments. We evaluate the original approach by applying it to data-rich stocks and comparing its predictions of status with the assessment model estimates. We refine the ORCS approach by: (1) developing a more predictive model of stock status that uses boosted classification trees to weight attributes by their relative importance, incorporate interactions between attributes, and account for non-linearity in attribute behavior; and (2) empirically identifying the best status-specific historical catch statistics and scalars for estimating overfishing limits using assessment model data. Finally, we evaluate the ability of the refined ORCS approach to estimate overfishing limits and compare the ability of the refined approach to estimate stock status to six other catch-only assessment methods.

2. Methods

2.1. Stock selection

We evaluated the ORCS approach to data-poor catch limit estimation by applying it to data-rich stocks with stock assessments based on underlying population dynamics models (generally statistical catch-at-age models, virtual population analyses, and