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Research Paper

Retrospective investigation of assessment uncertainty for fish stocks off southeast Australia

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ABSTRACT

There is a need to provide quantitative measures of uncertainty to support fisheries management decision making. A retrospective analysis of historical assessments for fish stocks off southeast Australia is conducted to quantify the extent of uncertainty associated with estimates of spawning stock biomass in absolute terms and when expressed relative to spawning stock biomass over a sequence of reference years. This approach to quantifying uncertainty captures more sources of uncertainty than alternative approaches, such as the estimate of the variance of terminal year spawning stock biomass from asymptotic methods, the extent to which estimates of spawning stock biomass vary among the sensitivity tests that form part of most assessments, and conventional retrospective analyses. By all measures, estimates of spawning stock biomass in absolute terms are much less certain than estimates of relative stock size (i.e. spawning stock biomass relative to a reference level), although application of most current harvest control rules rely on estimates of biomass in absolute terms. Overall, uncertainty in estimates of spawning biomass in absolute terms can be represented as a log-scale standard error of 0.37, while this standard error is 0.18 for estimates of spawning biomass in relative terms. There is considerable variation in among-assessment uncertainty in stock assessment outputs across species groups, with, for example, higher variation for assessments of chondrichthyans compared to other species.

1. Introduction

Management strategies for many of the world's major fisheries are based on harvest control rules, HCRs, which can be 'empirical' or 'model-based'. Empirical HCRs calculate management actions, such as limits on fishing effort or catch, as a function of data collected directly from the fishery (e.g., Butterworth and Punt, 1999; De Oliveira and Butterworth, 2004; De Moor et al., 2011). In contrast, 'model-based' HCRs use the outputs from stock assessments that fit population dynamics models to available monitoring data (e.g., IWC, 2012), and are by far the most common type of HCR implemented worldwide. The performances of model-based HCRs depend on the ability of the stock assessments to provide accurate (low bias) and precise (low variation) estimates of the quantities on which the HCR is based.

The HCRs on which fisheries management decisions for US fisheries are based include a buffer between the overfishing level (OFL) and the Acceptable Biological Catch (ABC) to account for scientific uncertainty. Various approaches have been developed to assess the extent of this source of uncertainty (Wiedenmann et al., 2017). The approach adopted for groundfish and coastal pelagic species off the US west coast involves calculating an ABC that is equal to the catch corresponding to F_{MSY} (the OFL) multiplied by a buffer that is less than 1.0 (i.e., ABC = (1 − buffer)*OFL). The buffer depends on the quality of the assessment (Category 1: catch-at-age, catch-at-length, or other data that inform a relatively data-rich, quantitative stock assessment; Category 2: some biological indicators that may include a relatively data-limited quantitative stock assessment or non-quantitative assessment; and Category 3: few available data) and is calculated based on a percentile of a lognormal distribution centered on the OFL. The standard deviation (σ) of this distribution depends on the Category, and is selected by the

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Table 1
Summary of Tier 1 assessment types applied to selected stocks in southeast Australian fisheries, including temporal coverage employed in assessments. Stocks indicated by an asterisk are those that are most valuable in the fishery and those indicated by & are above the target biomass. Stock Synthesis (SS).

Common name (stock)	Value (2014 – 15)[a] ('000 AUD)	Type of assessments	Number of assessments used	With consistent fishery-independent data	Range of years	Current depletion (based on the most recent assessment)	Most recent assessment
Shelf species							
Bight redfish	1266	Case-specific, SS	6	Yes	1960–2014	0.621 $^{\&}$	Haddon (2016)
Deepwater flathead	4230*	Case-specific, SS	7	Yes	1980–2015	0.448 $^{\&}$	Haddon (In press)
Jackass morwong (east)	399	Coleraine, SS	8	No	1915–2014	0.094	Tuck et al. (2016a)
Jackass morwong (west)	27	SS	5	No	1986–2014	0.630 $^{\&}$	Tuck et al. (2016b)
Redfish	232	Case-specific, SS	2	No	1915–2013	0.090	Tuck (2015)
School whiting	2513*	Case-specific, SS	5	No	1947–2008	0.434	Day (2010)
Tiger flathead	15,428*	Case-specific, SS	7	No	1915–2015	0.425 $^{\&}$	Day (in press)
Slope species							
Blue grenadier	1854	Case-specific, SS	12	Yes	1960–2012	0.777 $^{\&}$	Tuck (2014)
Blue warehou (east)	15	Case-specific, SS	4	No	1986–2008	0.153	Punt (2008)
Blue warehou (west)	15	Case-specific, SS	4	No	1986–2008	0.173	Punt (2008)
Gemfish (east)	224	Case-specific, SS	3	No	1968–2998	0.153	Little and Rowling (2009)
Ping ling (east)	195	SS	6	No	1970–2013	0.199	Whitten and Punt (2014)
Ping ling (west)	2071	SS	6	No	1970–2013	0.432	Whitten and Punt (2014)
Silver warehou	2450*	Case-specific, SS	8	No	1980–2014	0.316	Day et al. (2016)
Deep species							
Orange roughy (east)	0 (fishery closed)	Case-specific, SS	3	Yes	1980–2014	0.226	Upston et al. (2015)
Shark species							
Gummy shark (Bass Strait)	9085*	Case-specific	5	No	1927–2016	0.530 $^{\&}$	Punt et al. (In press)
Gummy shark (South Australia)	4460*	Case-specific	5	No	1927–2016	0.632 $^{\&}$	Punt et al. (In press)
Gummy shark (Tasmania)	1026	Case-specific	2	No	1927–2016	0.750 $^{\&}$	Punt et al. (In press)
School shark	1740	Case-specific	4	No	1927–2008	0.099	Thomson and Punt (2010)

[a] Source: Savage (2015), pro-rated based on catches by stock for 2014 and 2015 where the value was given by species in total (2013 for pink ling).

Scientific and Statistical Committee of the Council (in this case the Pacific Fishery Management Council), while the percentile of the log-normal distribution is selected by the Council given their risk tolerance and the consequences of precaution for fisheries for other stocks (PFMC, 2016a). That is, there are two steps to the setting the buffer, the setting of σ, which is purely scientific, and the selection of the degree of risk tolerance, which is a policy decision. The value of σ for stocks in Category 1 is set to the maximum of a default value (0.36), the coefficient of variation of the estimate of biomass for the most recent year, and the log standard error between the estimate of current spawning output from a base model and a low state of nature model that is meant to be half as likely as the base model. The value 0.36 was based on a meta-analysis of errors in estimating biomass from a retrospective analysis (Ralston et al., 2011), while the σ values for Categories 2 and 3 are respectively set to twice (i.e., 0.72) and four times (i.e., 1.44) the default for Category 1 stocks given the presumed additional uncertainty associated with data-limited and data-poor stock assessments.

Stock assessments for many stocks off southeast Australia (Table 1) are based, particularly recently, on similar methods of stock assessment to those applied to groundfish and coastal pelagic species off the US west coast, i.e., integrated analysis based on age-structured population dynamics models (e.g., Methot and Wetzel, 2013; see review of these approaches by Maunder and Punt, 2013). In addition, the HCRs adopted for "data-rich stock assessments" (Tier 1 stocks whose assessments provide "robust assessment of fishing mortality and biomass" – Dowling et al., 2016) are similar to those applied in the US.

No explicit buffer is included in the management strategy for Tier 1 stocks, although the target reference point for biomass is B_{MEY} (the biomass corresponding to Maximum Economic Yield, with a proxy of 48% of unfished spawning stock biomass, i.e., $0.48B_0$) rather than the biomass corresponding to Maximum Sustainable Yield, the proxy for which is $0.4B_0$. Management strategies based on catch curves and trends in catch-per-unit effort data have been developed for stocks for which no model-based assessments are available, i.e., 'data-poor' stocks (Wayte and Klaer, 2010; Little et al., 2011; Dowling et al., 2016). While the proxies used for targets in these management strategies are assumed to relate to $0.48B_0$, buffers are supposed to be included explicitly in the management strategies for these 'data-poor' (Tiers 2+) stocks.

This paper synthesizes the outcomes from multiple stock assessments conducted through time of finfish stocks harvested off southeast Australia (a "historical retrospective analysis"). Variation in estimated spawning biomass (or depletion) for a given year among multiple assessments of the same stock can arise from multiple sources: 1) chosen model structure; 2) fixed parameter values and prior distribution selection for other parameters; 3) increases in data availability; 4) composition of the review panel; 5) version of software employed and hence how the assessment can be specified; and 6) members of the stock assessment team conducting the assessment (Ralston et al., 2011). The objective of this paper is to estimate the between-assessment variation in estimates of spawning stock biomass (or pup production for chondrichthyan species), and how this variation compares with that for stocks off the US west coast (Ralston et al., 2011). It also considers whether estimates of relative biomass (biomass relative to a reference point) for southeast Australian stocks are less variable among assessments than estimates of biomass in absolute terms, as might be expected given results of simulation studies of the performance of stock assessment methods (e.g., Punt 1995, 1997; Magnusson and Hilborn, 2007).

Most recent model-based assessments for finfish stocks off southeast Australia have been conducted using Stock Synthesis (Methot and Wetzel, 2013) (Table 1), while historical assessments (generally pre-2004) were based on modeling platforms developed for specific stocks (as is still common in Australia, Dichmont et al., 2016a). We therefore also examine whether adoption of a common assessment platform has