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Assessing a multilevel tier system: The role and implications of data quality and availability

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ABSTRACT

Tier systems for fisheries assessment and management are widely used, but defined differently by jurisdiction. A principal component analysis was applied to the expanded Australian Commonwealth 8-tier system for fishery assessment and management to determine whether it adequately delineates across stocks according to data availability and quality. The original Australian tiers comprised four levels that were defined primarily according to the available stock assessment options, given the data availability and quality. We asked fishery experts to score information quality for each of the main Australian Commonwealth species and/or fisheries. Multivariate analysis indicated that the eight tiers delineated between the extreme tier levels on the first principal component, although there was overlap for intermediate tiers. More generally, it is important that the aim of tier systems and the basis for tier delineations are explicitly defined given the increasing association of tiers with trade-offs between overfishing risk, management cost and catch.

1. Introduction

Successful fisheries management requires a trade-off between maintaining fisheries at biologically sustainable levels, while ensuring economic sustainability, and effective but minimal management costs. Described as the "risk-cost-catch frontier" (Sainsbury, 2005; Dowling et al., 2013), there is an inherent assumption that the greater the risk of overfishing, the more precautionary management should be, and a trade-off follows that attempts to balance risk against the cost of management and catch levels (Little et al., 2015).

Across the United States, Europe and Australia, the risk-cost-catch trade-off is intended to be encapsulated, either implicitly (USA, Europe – International Council for the Exploration of the Seas (ICES)), or explicitly (Australia) using "tier" systems of assessment and management (*e.g.*, PFMC, 2014; ICES, 2012; Dowling et al., 2013; Smith et al., 2008, 2014; Dichmont et al., 2016). The higher the tier level (number), *i.e.* the more data limited, the greater the uncertainty and risk of overfishing, and so, presumably, the more conservative the recommended biological catch. The assumption is that there is greater risk of over-exploitation when data are poorer or fewer data are available, or if a formal stock assessment has not been undertaken.

The basis of current tier delineations vary by jurisdiction (Dichmont et al., 2016). For the USA west coast groundfishery and the Alaskan crab fishery, 3 or 5-level tier systems (PFMC, 2014; NPFMC, 2014) are delineated according to data availability, the ability to estimate quantities used in decision rules, and the perceived reliability of the resulting estimates of management-related quantities. The ICES system (ICES, 2012) is based on the ability of an assessment to estimate management quantities and data reliability.

In Australia, a four-level tier system was originally developed for the Southern and Eastern Scalefish and Shark Fishery (SESSF), primarily according to data quality and availability, given the available assessment options concordant with these (Smith and Smith, 2005). Tiers were based on the ability to produce a reliable assessment from the available data, which in turn defined the assessment method and the associated harvest control rule (HCR). The SESSF tier system attempted to apply a "discount factor" on the recommended biological catch for each tier to equalise risk (Smith

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Table 1
Criteria used to score quality and availability.

Score	0	1	2	3
Fishery-independent survey	Unbiased, low CVs	Unbiased, high CVS	Likely biased as indicators of trend, or poor spatial/temporal coverage	None
CPUE	Targeted fishery, and standardized	Bycatch/non-targeted fishery and standardized, and/or issues with spatial structure	Available but perhaps not standardized, or poor spatial/temporal/fleet coverage	None
Length-frequency	Representative of the whole fishery	Representative of at least one fleet/part of the fishery	Some data available	None
Catch-at-age	Representative of the whole fishery, ageing error known	Representative of at least one fleet/part of the fishery	Some data available	None
Total catch (including discards)	Whole fishery covered, data reliable and/or observer effort covered >50% of catch	Whole fishery covered; discard high and variable, and/or some uncertainty in reporting	Only landed catch; qualitative knowledge of bycatch, or high uncertainty in reporting, or poor spatial/temporal/fleet coverage	None
Landed catch	Well covered	Issues with stock identification, or catch uncertainty; discard high and variable	Issues with species identification, poor spatial/temporal/fleet coverage, and/or unreliable reporting	None
Effort	All sectors/fleets/participants covered	Multiple sectors with some not included, or not full coverage across fleets/participants	Poor spatial/temporal/fleet coverage, and/or unreliable reporting	None

Table 2
Harvest strategy tier levels (corresponding to an assessment and/or management framework), based on Dowling et al. (2013), and expanded from the 4-tier level system defined in Smith and Smith (2005) for the SESSF. Increasing tier numbers reflect an assumed increased risk of over-fishing. Note that, currently, no Australian stocks or species are assigned to tier 5, but this tier is included because it represents a level of data availability and an assessment intermediate in quality compared to Tiers 4 and 6 (Dowling et al., 2013).

Tier	Tier description
0	Robust (in terms of associated low confidence intervals) assessment of fishing mortality (F) and biomass (B), based on fishery-dependent and -independent data
1	Robust assessment of F and B based on fishery-dependent data only
2	Less robust assessment of F and B, based on fishery-dependent and/or fishery-independent data
3	Empirical estimates of F based on size and/or age data
4	Empirical estimates of either (a) trends in relative biomass based on catch-per-unit-effort (CPUE) data (b) within-season changes in relative biomass based on CPUE data (c) availability of relative biomass based on informal fishery-independent surveys
5	Empirical estimates of F based on the spatial distribution of effort relative to the distribution of the species
6	No estimate of biomass or F; management decisions based on fishery-dependent species-specific triggers
7	No estimate of biomass or F; management decisions based on fishery-dependent triggers for groups of species

et al., 2014), although this requirement for risk equivalency evolved over time and during its use. The aim was to acknowledge the amount and quality of data used for assessment, and the supposedly lower certainty associated with data-limited assessments; this was consistent with the requirements of the Australian Commonwealth Harvest Strategy Policy (DAFF, 2007). Implicit in this was the assumption that the cost of collecting more data at a higher-level tier would be offset by increased assessment certainty, and thus less precaution, in the recommended biological catches.

The question remains as to the most appropriate criteria by which assessment and management tiers should be delineated. Dichmont et al. (2016) recommended that tiers should not be defined simply on data and associated assessment availability, but also on the reliability of the stock assessments. A stock assessment could be considered to be "unreliable" when there is considerable sensitivity to changing some of its assumptions, when some key parameters (such as deviations about the stock-recruitment relationship) are not estimated, or when there are obvious retrospective patterns.

Dowling et al. (2013) describe an (unofficial) 8-level tier system based on the four tiers originally defined for the SESSF (Smith et al., 2008), while adding the remaining Australian Commonwealth harvest strategies. This new ordered tier system (numbered from 0 to 7, with the original SESSF tiers corresponding to tiers 1–4) attempts to accommodate more data-limited species and fisheries, with the aim of embracing a broader range of species and situations using existing Australian Commonwealth fishery harvest strategies. Here, we examine this expanded (8-level) tier system to determine the factors responsible for allocating Australian stocks into their respective tier level. This is valuable, as the assessment and decision rules beyond those developed for the SESSF have never before been evaluated as a unified system. This analysis forms an adjunct to Dichmont et al. (2016), and to a Management Strategy Evaluation (MSE) currently being undertaken to evaluate the risk-cost-catch frontier across tiers for Australian Commonwealth fisheries.

2. Methods

The availability and quality of data for the main species, or species groups, under each of Australia's Commonwealth (Federal) fisheries, was scored according to the guidelines in Table 1. The scoring system of 0–3 (highest to lowest), was used to score the following seven types of data: (1) Fishery-independent survey(s) (FIS) index, (2) catch-per-unit-effort (CPUE), (3) catch length-composition (CL), (4) catch age-composition (CA), (5) total landed catch including estimates of discards, illegal catch, *etc.* (totC), (6) landed catch (C), and (7) effort (E).

If CPUE data are available, it follows that so are some effort data. Data categories (6) and (7) of Table 1 ('landed catch' and 'effort') were intended to apply more to fisheries for which only either catch or effort data are available, and where these form the basis for "assessments". Such fisheries include multispecies fisheries where catch is not reported by species, or fisheries for which catch data

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