Fisheries Research 171 (2015) 141–153

Contents lists available at ScienceDirect

Fisheries Research

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

Empirical harvest strategies for data-poor fisheries: A review of the literature

N.A. Dowling[a,*], C.M. Dichmont[b], M. Haddon[a], D.C. Smith[a], A.D.M. Smith[a], K. Sainsbury[c]

[a] CSIRO Oceans and Atmosphere Flagship, Castray Esplanade, Hobart 7001, TAS, Australia
[b] CSIRO Oceans and Atmosphere Flagship, 41 Boggo Road, Dutton Park, Brisbane 4102, QLD, Australia
[c] Institute of Marine and Antarctic Studies, University of Tasmania, 20 Castray Esplanade, Battery Point, 7004, TAS, Australia

ARTICLE INFO

Article history:
Received 30 April 2014
Received in revised form 15 October 2014
Accepted 19 November 2014
Handled by A.E. Punt
Available online 29 December 2014

Keywords:
Data-poor fisheries
Data-poor harvest strategies
Empirical harvest strategies
Empirical decision rules
Harvest strategy framework
Literature review

ABSTRACT

Harvest strategy approaches based around empirical indicators and/or control rules are beginning to be accepted in a growing range of data- and capacity-poor fisheries. While there is an increasing body of work around developing empirical indicators and control rules in data-poor contexts, this has typically been done on a case-specific basis. There remains a need for general guidance on formulating control rules that link empirical indicators with suitable management responses. Additionally, in the data-poor context, most literature has focused on empirical indicators and assessments, with less focus on decision rules and the incorporation of indicators and assessments in a harvest strategy framework. This review considers a range of harvest strategy options, focusing on empirical indicators and decision rules available for data-poor species and fisheries. These clearly illustrate that a paucity of information is not a reason to avoid developing harvest strategies, and that a range of pragmatic approaches are available regardless of the available data, life-history of the target species, nature of fishing operations, or the available research capacity. There is considerable scope for further work in this field, but arguably there is a comprehensive repository of approaches and decision rules that, when combined with the guidelines, form a solid foundation and toolkit for all but the most data-poor species and fisheries.

1. Introduction

There has been considerable focus recently on the development of tools to assess and manage data-poor fisheries. This is not surprising given that the majority of stocks exploited globally are categorised as data poor (Costello et al., 2012) and their status, though very uncertain, is thought to be overall worse than for data-rich stocks (Worm and Branch, 2012). Much of the focus of this tool development to date has been on improving methods to assess the status of such resources (e.g. Carruthers et al., 2012, 2014; Dick and MacCall, 2010; Kruse et al., 2005). To date there has been less focus on the tools needed to manage data-poor stocks, but this is starting to change. This paper reviews recent work to develop harvest strategies for data poor stocks, focusing particularly on harvest strategies that use empirical indicators of stock status.

Harvest strategies (HSs, "management strategies", "management procedures") are formal frameworks for managing exploitation of fisheries, usually applied to the target species (e.g. Sainsbury et al., 2000; Butterworth and Punt, 2003, and Fish. Res. Special Issue 94(3) 2008). They comprise a fully-specified set of rules for making tactical management decisions including specifications for (i) a monitoring program, (ii) the indicators to be calculated from monitoring data (usually via a stock assessment) and (iii) the use of those indicators and their associated reference points in management decisions, through application of decision (or control) rules (Butterworth, 2007; Butterworth and Punt, 2003; DAFF, 2007; Punt et al., 2002; Rayns, 2007; Sainsbury et al., 2000). We define a "harvest strategy framework" as the approach taken to the selection of indicators to determine the resource status relative to reference points, and how and when decision rules will be invoked.

A significant challenge is to develop harvest strategy frameworks that reconcile the reality and limitations of data-poor fisheries with fundamental fishery objectives, such as ceasing or avoiding overfishing, rebuilding overfished stocks, and maintaining stocks at some target level (Bence et al., 2008; Cadrin and Pastoors, 2008). These objectives imply some knowledge of stock biomass

* Corresponding author. Tel.: +61 3 6232 5148; fax: +61 3 6232 5012.
E-mail addresses: natalie.dowling@csiro.au (N.A. Dowling), cathy.dichmont@csiro.au (C.M. Dichmont), malcolm.haddon@csiro.au (M. Haddon), david.c.smith@csiro.au (D.C. Smith), tony.d.smith@csiro.au (A.D.M. Smith), ksainsbury@netspace.net.au (K. Sainsbury).

http://dx.doi.org/10.1016/j.fishres.2014.11.005
0165-7836/

Table 1
Examples of harvest strategies organised by data richness and type of indicator used; this review focuses on harvest strategies for data-poor fisheries based on empirical indicators.

Indicator	Data poor	Data moderate	Data rich
Empirical	Queensland spanner crab[1]	Australian swordfish[2]	South African hake[3]
Model-based	NA[6]	US rock fish[4]	Australian jackass morwong[5]

[1] Dichmont and Brown (2010).
[2] Prince et al. (2011).
[3] Rademeyer et al. (2008).
[4] Cope et al. (2013).
[5] Wayte (2013).
[6] None currently used; future harvest strategies could be based on data poor assessment methods that provide estimates of F, e.g. the SAFE method (Zhou et al., 2009).

and/or exploitation status (such as fishing mortality rate), whereas for data-poor stocks these values are not generally available (Cadrin and Pastoors, 2008).

The information base to assess and manage fish stocks covers a broad spectrum, from data-poor to data-rich. Most of the theory and practice of fish stock management has been built around data-rich stocks, where assessments of stock status use dynamic population models fitted to long time series of catch, effort, size and age data, as well as (desirably) fishery independent resource surveys. At the other end of the spectrum, data-poor stocks may have only occasional estimates of catch. Dowling et al. (2013) describe this spectrum as a set of "tiers", from tier 0 (data rich) to tier 7 (data poor). Separately, the actual indicators used to inform harvest strategies can vary from empirical to model-derived. Empirical indicators are those measured more or less directly from monitoring data (e.g. survey biomass estimates, catch rates (CPUE), mean length of fish in the catch, catch levels, etc. Model-derived indicators are usually estimates of either abundance (e.g. biomass B or depletion D) or exploitation rate (e.g. fishing mortality rate F). Table 1 illustrates that for harvest strategies these two dimensions (data richness and type of indicator) are orthogonal to each other—empirical indicators can be used in both data-rich and data-poor situations (and positions in between), and likewise model-derived indicators. This review focuses mainly in the top left panel of Table 1—harvest strategies for data-poor fisheries based on empirical indicators.

Harvest strategy approaches based around empirical indicators and/or control rules are beginning to be accepted in a growing range of data-poor fisheries (Bentley et al., 2005; Cheung and Sadovy, 2004; Davies et al., 2007; Dichmont and Brown, 2010; Dowling et al., 2008a,b; Edwards et al., 2012; Kolody et al., 2010; Parma et al., 2006). Data-poor fisheries are characterised by (a) uncertainty in the status and dynamics of the stock or species, (b) uncertainty in the nature of fishing (e.g. in terms of fleet dynamics and targeting practices), (c) having only basic or no formal stock assessments, and/or (d) having a low gross value of production (GVP). Often even proxy biomass estimates are unavailable and, where there is low GVP or capacity, it is unlikely that reliable biomass estimates would ever be obtained. Note that data-poor stocks or species can also occur in an otherwise data-rich or data-moderate fishery.

Empirical harvest strategies use empirical indicators and/or empirical decision rules. They are not constrained by the need for quantitative population models. As quantitative models can rarely be applied to data poor fisheries, empirical harvest strategies are often more applicable to data poor fisheries management. Empirical decision rules are based on directly observable indicator(s) or performance measures (the relationship of an indicator to a reference point), rather than on those estimated from stock assessment models (e.g. spawning stock biomass and/or fishing mortality). Nevertheless empirical indicators should provide some measure or proxy that can be related to exploitation status. Examples of empirical indicators include catch-per-unit-effort; the mean, median or percentiles of the length; the weight distribution of the catch, or, in very data-poor fisheries; catch or effort levels. For multispecies fisheries with no fixed target species, indicators can be based on the spatial distribution of fishing activity or on catch species composition (Dowling et al., 2008a). The challenge is to relate empirical indicators to stock status and to management objectives.

While there is an increasing body of work around developing empirical indicators and decision rules for data-poor species and fisheries, these have typically been developed on a case-by-case basis. As stated above, for data- and capacity-poor fisheries, most literature has focused on empirical harvest strategies and assessments, with the latter having been reviewed extensively elsewhere (see for example, Berkson et al., 2011; Carruthers et al., 2012, 2014; Dick and MacCall, 2010; Kruse et al., 2005; Mar. Coastal Fish. Special Section Volumes 1 and 2 2009, 2010; Pilling et al., 2008). There has, however, been much less focus on decision rules and the incorporation of empirical indicators and assessments in a harvest strategy framework. For example, Ye et al. (2011) emphasised the need for empirical or knowledge-based indicators for data-limited fisheries, and identified various indicators for the Northern South China Sea fishery. However, corresponding reference points were not defined and, despite acknowledgement of the importance of harvest strategies, no such framework was proposed.

This review summarises the literature describing empirical harvest strategies for data poor fisheries. It is not a review of data-poor assessment methods but reference to these is included where relevant. The first section describes indicators, while the second section focuses on decision rules for empirical data-poor harvest strategies (Table 2). This review complements the guidelines for harvest strategy development discussed in Dowling et al. (2014).

2. Indicators for empirical data poor harvest strategies

For harvest strategies based on empirical indicators, the indicators essentially replace having an assessment of stock status based on models. However the indicators still need to reflect stock status in some way, so that changes in those indicators can be used (by the harvest strategy) to steer the stock towards meeting management goals. Indicators are the key "inputs" into a harvest strategy. The key outputs are the actual management decisions resulting from the decision rules, discussed in the next section.

Even in data-poor fisheries, indicators should reflect whether the stock is in an acceptable state, in an unacceptable state, or somewhere in between. These conditions would be analogous to being at or above a specified target reference point, at or below a limit reference point, or somewhere between the two. Determining status can be done solely using empirical indicators, such as catch, effort, length frequencies, or other available information, provided they can be interpreted in appropriate ways. Indicators can be based on qualitative information, but such indicators should be replaced or updated as more is learnt about a fishery; this is especially the case in a developing fishery in which even proxies for targets and limits would initially be impossible to select.

This section is organised by describing harvest strategy frameworks based on single or multiple indicators, where multiple indicators can either be used sequentially, collectively, or hierarchically.

2.1. Single indicator harvest strategy frameworks

2.1.1. Use and evaluation of single indicators

One form of indicator may be all that is available for data-poor species or fisheries. In the simplest application, reference points