Fisheries Research 168 (2015) 49–55

Contents lists available at ScienceDirect

Fisheries Research

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

How much evidence is required for acceptance of productivity regime shifts in fish stock assessments: Are we letting managers off the hook?

Neil L. Klaer[a,*], Robert N. O'Boyle[b], Jonathan J. Deroba[c], Sally E. Wayte[a], L. Richard Little[a], Larry A. Alade[c], Paul J. Rago[c]

[a] CSIRO Oceans and Atmosphere, PO Box 1538, Hobart, Tasmania, Australia
[b] Beta Scientific Consulting Inc., 1042 Shore Dr. Bedford, Nova Scotia, Canada B4A 2E5
[c] NOAA Fisheries Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543, USA

ARTICLE INFO

Article history:
Received 12 November 2014
Received in revised form 25 March 2015
Accepted 25 March 2015
Handling Editor A.E. Punt
Available online 20 April 2015

Keywords:
Productivity shift
Regime shift
Fisheries

ABSTRACT

A difficult question often confronting fisheries assessment scientists and managers is whether or not to accept that a shift in stock productivity has occurred. This is particularly the case when a stock has remained at historically low biomass despite management intervention and when there is an expectation that there should have been a stock recovery. We outline a weight-of-evidence approach that provides a structured means to evaluate this question. The approach, which scores a range of attributes, was applied to five fisheries from the NW Atlantic and SE Australia, chosen to provide a range of supporting evidence, as well as different potential causal mechanisms for a productivity shift. Given the resulting scores for the example stocks, and whether a productivity shift has been accepted for those stocks, a score of between 7 and 12 indicated a level required for acceptance of a productivity shift. The approach has highlighted areas of future research that would improve individual species scores. It is hoped that the paper will encourage a more systematic examination of potential stock productivity shifts in assessments than has hereto been the case.

1. Introduction

A question often confronting fisheries assessment scientists and managers is whether or not a shift in stock productivity has occurred. This is particularly the case when a stock has remained at historically low biomass despite management intervention and when there is an expectation that there should have been a stock recovery.

For the purposes of this paper, a productivity shift is defined as a change over time in the biological characteristics of a fish stock that would lead to a change in biological reference points (such as maximum sustainable yield). In estimating biological reference points, it is often assumed that natural mortality, length-at-age, length–weight relationship, maturity-at-age/-length and the relationship of recruitment to spawning stock biomass are constant through time. A substantial temporal change in any of these factors would cause what we call a productivity or regime shift in the stock. Our focus is thus how best to interpret potential productivity shifts from a stock assessment and management advice viewpoint.

The decision on whether or not there has been a change in stock productivity is a difficult one. Accepting that there has been a shift in productivity moves the cause of the (usually) low biomass away from fishing to an external cause such as unfavourable environmental conditions. The responsibility for low stock status is thus removed from fisheries management as the cause is out of management control, and management is therefore "off the hook". On the other hand, if the stock biomass is low and productivity has not changed, there can be severe consequences for the future yield prospects of the resource – possible fishery closure or severe restriction of fishery effort.

Because of the potentially significant effect on biological reference points, a productivity shift might be described as an "extraordinary claim" and, as Sagan (1980) put it, "extraordinary claims require extraordinary evidence." Unfortunately, in our experience, decisions on whether or not there has been a productivity shift that should be taken into account in a stock assessment are often not based upon a systematic review of the available evidence but rather on expert opinion, which can be influenced by preconceptions. We contend that as acceptance of a productivity shift can have a very a profound influence on stock status and management

* Corresponding author. Tel.: +61 419107625; fax: +61 362325000.
E-mail address: neil.klaer@csiro.au (N.L. Klaer).

http://dx.doi.org/10.1016/j.fishres.2015.03.021
0165-7836/

responsibility, an evidence-based approach is required to justify such acceptance.

A weight-of-evidence approach allows qualitative and semi-quantitative rating and assessment of the available scientific evidence in relation to some causal hypothesis or hypotheses (Krimsky, 2005). Importantly, hypotheses are articulated prior to the evaluation and then the evidence for – and against – each is evaluated. Note that this is similar to the Information–Theoretic approach used in quantitative model selection (Burnham and Anderson, 1998). Indeed, statistical model fitting involves the selection of the hypothesized processes which maximize the probability that the selected model gave rise to the observed data. However, in many assessments (if not most), models have not been developed that allow full quantitative exploration of the evidence for competing hypotheses. The default position has been that processes not included in a model are not considered. We suggest that it is prudent and necessary to evaluate support for competing hypotheses using a qualitative approach until such time as models can be developed to do so.

2. Methods

A weight-of-evidence approach can be used to decide whether a species has undergone a productivity shift that needs to be taken into account in a stock assessment. An advantage of the approach is that it provides an objective basis for what would otherwise be a subjective decision. A disadvantage is that the actual mechanism used to assign weightings to components and arrive at a decision may not be transparent (Krimsky, 2005). It is therefore important to test the proposed process(es) against verifiable examples.

We developed four criteria that we believe should be used to decide if there has been a productivity shift in a stock or population. These criteria are described below. Judgement using a weight-of-evidence approach is facilitated by assignment of a numerical score against each criterion.

2.1. Criteria for judgement of productivity shift

2.1.1. Criterion 1. Observed change in a productivity indicator

A productivity indicator is an observation over time of change in some measure of the stock that potentially provides evidence for a change in productivity regardless of the level of fishing pressure. Such indicators may include recruitment estimates from egg, larval or young-of-the-year surveys, biomass estimates from fishery catch rates (CPUE) or fishery-independent surveys, or evidence of changing natural mortality from multi-species diet studies or observed fish kills.

A long period of change in an indicator such as available biomass despite management intervention, is usually the cause for first consideration of a productivity shift. Some fish stocks show more obvious signs of a productivity shift than others, so the degree of change in the relative level of the indicator should also be considered in the overall weight of evidence. Fish stocks often only receive attention when the observed shift is to an apparent state of lower productivity. Of course, the opposite is also possible and should also receive critical evaluation.

A long period is probably best interpreted from a stock management perspective. This would be a period of sufficient length for evidence of a disconnection between management expectations and the response of the fish stock. Often this would be related to the average generation time or maximum age of a species. For example, a high score would be given if fishing pressure was reduced to negligible levels on a stock for a period of multiple generations, but no increase in biomass has been observed with a high degree of precision (e.g. through intensive fishery independent surveys).

2.1.2. Criterion 2. Understanding of assessment model input data

This criterion applies to the quality of the observations on which a stock assessment model is based. Fundamental biological characteristics such as age-/length-at-maturity, the length–weight relationship, differences in growth/reproduction by sex are normally gained via targeted biological studies. Uncertainty in such information should be considered under this criterion.

In addition, for many stocks, there is uncertainty about spatial stock boundaries that affects many observation uncertainties. Catch history may also be uncertain due to lack of records, estimation of total catch based on discard mortality rates, or difficulty in separating similar species in commercial landings. Similarly, abundance indices may be noisy due to low sampling levels, show inconsistent trends, or are possibly biased if survey methodology has changed or sampling has occurred at the margins of the spatial or depth distribution of the stock. Similar sources of error also apply to sampling of age or length composition.

Low scores of this criterion apply when there is substantial uncertainty in the biology, total fishery catch, recent levels of fishing mortality, whether abundance indices are likely to be good indicators of true population abundance, or whether age/size sampling has been representative of the population.

If it is not possible to resolve such uncertainties, the score can be increased through the development of plausible ranges of alternative assessment inputs, at least for model sensitivity testing.

2.1.3. Criterion 3. Understanding of assessment model structural assumptions

This criterion applies to the extent it can be determined that an apparent time-varying shift in productivity is not a product of the structural assumptions of the assessment model. It is important to determine whether an apparent change in a parameter through time reflects an actual shift rather than the application of an inappropriate average relationship. For example, an inappropriate relationship might occur if recruitment is assumed to remain constant at all biomass levels when a model fit to data indicates a recruitment pattern better characterised by a Beverton and Holt (1956) stock–recruitment relationship. In a less extreme case, the model may assume a certain fixed value for Beverton and Holt steepness that results in apparent time-shifts in average recruitment residuals, which can be corrected using a different steepness value.

Not accounting for substantial shifts in fishery selectivity (e.g. dome shaped to logistic) over time may contribute to a perception of productivity shift, and should be closely examined if this is a possibility. Conversely, the introduction of a substantial selectivity change to an assessment model requires close scrutiny of the supporting evidence.

The lowest score level should result from the simple display by the model of an apparent change in the average of an important productivity parameter over a period of time. A higher score applies if the addition of time variation in a parameter is justified statistically (e.g. via Akaike information criterion or removal of a retrospective pattern), if alternative model structures that do not require time variation were considered and excluded, and if other possible sources of productivity change were also investigated. A more complete list of possible time-varying productivity parameters for a single species population model would include recruitment, fishery selectivity, natural mortality, growth, age/length at maturity, and fecundity.

Currently, most integrated assessment models routinely only allow for annual variation in recruitment, so this parameter is most often identified in stock assessments as potentially showing long periods of average change. As key population parameters are usually confounded, appropriate data are required to allow the assessment model to separately estimate time trends in several