Ecological Economics 97 (2014) 101–109

Contents lists available at ScienceDirect

Ecological Economics

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

Analysis

Detecting the presence of depensation in collapsed fisheries: The case of the Northern cod stock☆

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ARTICLE INFO

Article history:
Received 22 October 2012
Received in revised form 15 November 2013
Accepted 16 November 2013
Available online xxxx

Keywords:
Stochastic population dynamics
Compensation
Depensation
Northern cod collapse
Splines
Demographic uncertainty

ABSTRACT

Motivated by the evidence that many collapsed stocks have failed to recover despite the fact that fishing mortality has been reduced, or even when a moratorium is in effect, we develop a methodological approach using splines to analyze the stochastic population dynamics of fish stocks at low stock levels. Considering the aggregate Northern cod stock by way of illustration, we find that the species' lack of recovery, despite the moratorium which still remains in force, is consistent with the hypothesis of depensatory population dynamics at low population sizes, as opposed to the compensation estimated by the conventional regression methods used in classic bioeconomic models.

1. Introduction

The aim of this paper is to provide a simple stochastic mathematical model using a total biomass approach to detect depensation in collapsed fisheries. Specifically, we develop a methodological approach using, at low stock levels, splines (cubic polynomials) which are more flexible than the quadratic or logistic functional forms used in conventional regression methods.

The biomass approach, also termed surplus production model, is widely used in the literature on fisheries economics to describe fish population dynamics and specifies population size and growth in terms of total biomass (Clark, 2006). In this setting, conventional regression methods are used by classic bioeconomic models to find the curve of best fit for the stock data between the families of logistic curves. Since all of these curves are concave this approach accepts the a priori hypothesis of compensatory dynamics at low population sizes in which the intrinsic growth rate increases as the population decreases (e.g. Nøstbakken and Bjørndal, 2003 for the case of North Sea herring).

Conversely, finding the best-fitting spline does not require any a priori assumption and allows us to detect changes in the concavity of the growth function of the species at low population sizes caused by a severe decline in biomass. The focus here is to model the stochastic aggregate stock dynamics of collapsed fisheries.

The implication underlying compensation is that marine fishes are highly resilient to large population reductions thanks to a strong inherent capability to recover from low population sizes. However, there is very little evidence for population recovery from prolonged declines (Hutchings, 2000; Hutchings and Reynolds, 2004; Murawski, 2010). One of the most dramatic cases is the collapse of the Northern cod stock (NCS). 21 years after imposing a moratorium the fishery has not yet recovered. Using the biomass approach for the pre-moratorium period and conventional regression methods the literature on fisheries economics has estimated compensation at low population sizes (Grafton et al., 2000, 2009; Ussif et al., 2004).

The literature on the population dynamics of fish stocks has dealt extensively with the fact that compensation, as estimated by classic bioeconomic models, is unable to cope with the lack of recovery of fish population collapses. Biological mechanisms supporting depensation (per capita growth rate decreases as the population is reduced) and critical depensation (per capita growth rate becomes negative for low enough stock values) have been widely studied (e.g. Frank and Brickman, 2000; Liermann and Hilborn, 2001; Shelton and Healey, 1999). These may include overfishing-induced phenotypic changes to life history parameters (Denney et al., 2002; Hutchings and Reynolds, 2004; Olsen et al., 2004), cultivation–depensation effects (Myers and Worm, 2005; Walters and Kitchell, 2001), unobserved genetic or behavioral diversity due to a complex structure of depleted stocks (Frank and Brickman, 2000; Sterner, 2007), changes in habitat (Hutchings, 2000),

☆ This research has been supported by the Spanish Ministry of Education, research project MICINN 2012, ECO2012-39098-C06-00.
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http://dx.doi.org/10.1016/j.ecolecon.2013.11.006