Fisheries Research 155 (2014) 64–73

Contents lists available at ScienceDirect

Fisheries Research

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

Varying components of productivity and their impact on fishing mortality reference points for Grand Bank Atlantic cod and American plaice

M.J. Morgan*, P.A. Shelton, R.M. Rideout

Fisheries and Oceans Canada, PO Box 5667, St. John's, NL A1C 5X1, Canada

ARTICLE INFO

Article history:
Received 6 August 2013
Received in revised form 12 February 2014
Accepted 17 February 2014
Handling Editor George A. Rose
Available online 20 March 2014

Keywords:
Productivity
Reference points
Recruitment
Maturity
Weight

ABSTRACT

Population productivity is determined in large part by growth, maturity and recruitment. This determines the level of fishing that the population can sustain without declining. We examined how these components of productivity have varied during warm and cold periods for two Grand Bank fish populations, and how this variation affects fishing mortality reference points. Productivity of both Div. 3NO Atlantic cod and Div. 3LNO American plaice has varied considerably over time. Projections of population size under different conditions showed that the level of recruits per spawner played a major role in determining the level of fishing mortality that did not result in population decline. For plaice there was also a substantial impact of varying proportion mature at age. The impact of factors other than temperature on recruits per spawner and maturity meant that the association of productivity with temperature was not consistent. When productivity was at its lowest, the level of fishing mortality that could be sustained without causing rapid population decline was very low. The results of this study clearly demonstrate that the impacts of changing productivity can be rapid and very large and if fishing mortality reference points are not adjusted accordingly the results can be catastrophic. It may be helpful to develop fishing mortality reference points that incorporate all components of productivity and are updated using only recent data. Such reference points could be used in combination with buffers around a biomass limit reference point (B_{lim}) and/or low risk tolerances for declining below B_{lim} to account for the uncertainties that would remain even in frequently updated reference points.

Crown Copyright © 2014 Published by Elsevier B.V. All rights reserved.

1. Introduction

The productivity of a fish population is the capacity of that population to produce biomass, and is a result of increases due to growth and reproduction, countered by declines due to mortality. The productivity of a fish population determines the level of fishing that can be sustained without a decline in population size. Major components of productivity are recruitment, weight at age, maturity at age and mortality. These components vary over time and therefore, so too does the overall productivity of the population. Recruitment is linked to the size (i.e. biomass or abundance) and composition of the spawning stock and is also affected by environmental conditions (Myers and Barrowman, 1996; Shepherd et al., 1984; Cushing, 1996). Growth varies with temperature and prey availability (Brett, 1979; Shelton et al., 1999; Bjornsson et al., 2001). Maturity has been shown to vary with temperature and mortality and is related to growth (Kjesbu et al., 1998; Morgan and Colbourne, 1999; Olsen et al., 2005). Estimates of natural mortality are few but it is not constant over time and can be influenced by environmental conditions and changes in predation level (Dutil and Lambert, 2000; Sinclair, 2001; Morgan and Brodie, 2001; Chouinard et al., 2005).

Fishing mortality (F) reference points play an important role in the management of many fisheries and are determined by population productivity. As the components of productivity vary, so too do the reference points derived from them (A'mar et al., 2009; Brooks, 2013; Heino et al., 2013; Wayte, 2013). These reference points can be targets to be achieved or limits that should be avoided (Caddy and McGarvey, 1996). Three of the most commonly used fishing mortality reference points are F_{MSY}, $F_{0.1}$ and $F_{40\%SPR}$. $F_{0.1}$ is generally used as a target, $F_{40\%SPR}$ is a limit, while F_{MSY} is used as both, depending on the fisheries management jurisdiction. F_{MSY} is the fishing mortality giving the maximum sustainable yield from a population (Schaefer, 1954). Fishing at levels above F_{MSY} will result in a population size that is lower than B_{MSY}, the biomass giving maximum sustainable yield (MSY). $F_{0.1}$ is determined as the F where the slope of the yield per recruit (YPR) curve is 10% of the slope at the

* Corresponding author. Tel.: +1 709 772 2261; fax: +1 709 772 4188.
E-mail address: Joanne.morgan@dfo-mpo.gc.ca (M.J. Morgan).

http://dx.doi.org/10.1016/j.fishres.2014.02.019
0165-7836/Crown Copyright © 2014 Published by Elsevier B.V. All rights reserved.

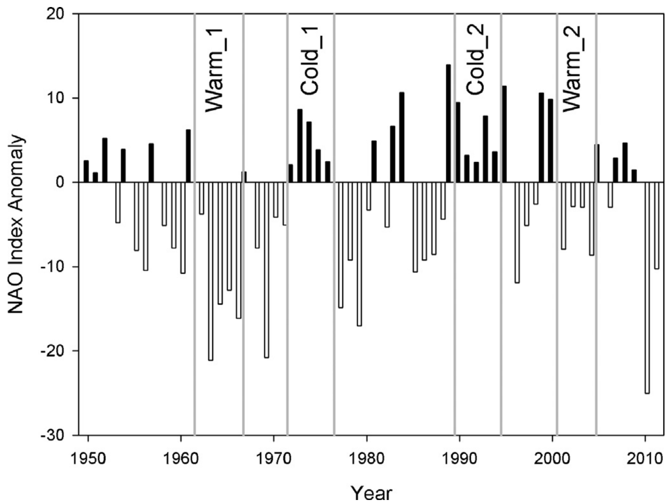

Fig. 1. Rogers North Atlantic Oscillation (NAO) anomaly (millibars of pressure) relative to the 1981–2010 average. The warm and cold periods examined are indicated. Warm_1 is 1962–1966, Cold_1 is 1972–1976, Cold_2 is 1990–1994 and Warm_2 is 2001–2004.

origin. $F_{40\%SPR}$ is the F that reduces spawner per recruit (SPR) to 40% of the unfished value. Changes in population productivity will influence the estimation of these three reference points differentially because they incorporate different components of productivity in their calculation. F_{MSY} is determined by all components of productivity and will therefore be affected by changes in any component of the productivity of the population (Morgan et al., 2009; Brooks, 2013). Reference points derived from YPR or SPR do not include the recruitment component of productivity. YPR based reference points will respond only to variation in growth while SPR reference points will respond to changes in growth and/or maturity.

If changes in productivity are short term, then the impact of assuming constant conditions is likely to be small. However, extended periods of low productivity could result in population decline if F is set at a reference point level based on an assumption of constant, more productive, conditions (Cook and Heath, 2005; Koster et al., 2009). Cold or warm ocean temperatures can persist for several to many years (Colbourne et al., 2012). To understand how productivity will differ and which reference points will respond to this variation, it is important to understand how the components of productivity may change with varying environmental conditions (Kell et al., 2005).

Major variation in ocean temperature has been observed on the Grand Bank in the Northwest Atlantic off Newfoundland Canada over the last 50 years. There was an extended period of warm temperature in the 1960s, while the early 1970s and early 1990s were generally cold, with recent years once again characterized by warm ocean temperature (Colbourne, 2004; Colbourne et al., 2012). Thus there has been the potential for lengthy periods of high and low productivity of fish stocks in the area, driven by the direct and indirect effects of temperature. Northwest Atlantic Fisheries Organization (NAFO) Division 3NO Atlantic cod (*Gadus morhua*) and Div. 3LNO American plaice (*Hippoglossoides platessoides*) are two important groundfish populations on the Grand Bank. Both experienced severe population decline due to over fishing and spawning stock biomass (SSB) for both stocks is currently at a low level (Power et al., 2010; Rideout et al., 2011). They have also both exhibited major changes in maturity at age that may have been related, in part to temperature. Growth has also been shown to be related to temperature, although weakly, for Div. 3NO cod and for Div. 3LNO plaice, cohorts that grew faster and occupied warmer temperatures were those that matured earlier (Morgan and Colbourne, 1999; Morgan et al., 2010). There is also evidence that recruitment rate is related to ocean climate in these two populations (Stige et al., 2006; Halliday and Pinhorn, 2009). The extended warm and cold periods, coupled with the fact that components of productivity are influenced by temperature, suggest the potential for long term changes in productivity of these two Grand Bank fish populations.

In this study we examine time series of abundance and biological data on these stocks for indications of changes in weight at age, maturity at age and recruitment rate, during warm and cold periods. We estimate F_{MSY}, $F_{0.1}$, and $F_{40\%SPR}$ using the productivity from these periods and determine which components of productivity (recruitment, weight at age, maturity at age) are responsible for any differences. We also explore the implications of failing to recognize changes in stock productivity by examining the consequences of fishing the populations when they are at one level of productivity at reference points derived from a different level of productivity.

2. Materials and methods

2.1. Productivity

The Grand Bank has experienced warm and cold periods over the last half century. The 1960s and 2000s were generally warm while the early 1970s and the early 1990s were cold years (Colbourne, 2004; Colbourne et al., 2012). We chose years within these time periods based on anomalies in the North Atlantic Oscillation (NAO), an index of ocean climate on the Grand Bank (Colbourne, 2004), as a basis for comparisons of productivity. The years 1962–1966 (Warm_1), 1972–1976 (Cold_1), 1990–1994 (Cold_2) and 2001–2004 (Warm_2) were chosen to represent the 1960s, 1970s, 1990s and 2000s respectively (Fig. 1). These were years with consistently high (cold) or low (warm) NAO. For the first three periods five years were chosen in order to have the same number of years in each period. The 2000s were more variable and so there was only a 4-year period with a consistent NAO during which population data were available.

All analyses and data are based on information from recent assessments of Div. 3NO cod (Power et al., 2010) and Div. 3LNO American plaice (Rideout et al., 2011). Model estimates of population numbers at age in each year were extracted for each stock. Stock weights at age (for calculating SSB) and catch weights at age (for calculating catch) were based on commercial sampling conducted for these assessments. Maturities at age in these assessments were modeled by cohort based on research vessel data. SSB was calculated as the sum of the product of model estimates of numbers at age (both sexes combined), model estimates of female proportion mature at age, and beginning of year stock weights at age (both sexes combined). Recruitment was calculated from the assessments as number at age 1 such that

$$r = N_{\text{agerec}} \times e^{M \times a} \tag{1}$$

where N_{agerec} is the number of recruits and a is difference between the age at recruitment estimated in the assessment and age 1. For 3NO cod a is 1 and 4 for 3LNO American plaice. M is natural mortality and was set equal to 0.2 for 3NO cod for all years. For 3LNO American plaice M was 0.2 for all years except from 1989 to 1996 when it was 0.53, as is the case in the assessment, to include an increase in natural and other unaccounted for mortality over that period (Morgan and Brodie, 2001).

Weight at age, maturity at age, recruits per spawner (RPS), and spawner per recruit (SPR) at $F = 0$ were examined to determine how they differed among Warm_1, Cold_1, Cold_2, Warm_2 and average conditions. For each period, average weights, maturities and RPS were calculated. Variation in recruitment was expressed as RPS as

Download English Version:

https://daneshyari.com/en/article/4542948

Download Persian Version:

https://daneshyari.com/article/4542948

Daneshyari.com