Deep-Sea Research II 107 (2014) 40–53

Contents lists available at ScienceDirect

Deep-Sea Research II

journal homepage: www.elsevier.com/locate/dsr2

Toward biophysical synergy: Investigating advection along the Polar Front to identify factors influencing Alaska sablefish recruitment

S. Kalei Shotwell[a],*, Dana H. Hanselman[a], Igor M. Belkin[b]

[a] Auke Bay Laboratories, Ted Stevens Marine Research Institute, Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 17109 Pt. Lena Loop Rd, Juneau, AK 99801, USA
[b] Graduate School of Oceanography, University of Rhode Island, 215 South Ferry Road, Narragansett, RI 02882, USA

ARTICLE INFO

Available online 27 August 2012

Keywords:
Polar Front
Oceanic front
Sablefish
Groundfish
Stock assessment
Prediction
Modeling
Recruitment
Advection
Sea surface temperature
Gulf of Alaska
Alaska
North Pacific

ABSTRACT

In fisheries stock assessment, reliable estimation of year-class strength is often hindered by lack of data on early life history stages and limited knowledge of the underlying environmental processes influencing survival through these stages. One solution to improving these estimates of year-class strength or recruitment is to first develop regional indices representing the spatial and temporal extent of a hypothesized feature influencing a species' recruitment. These covariates should then be integrated within a population model where a variety of model selection techniques may be conducted to test for a reduction in recruitment uncertainty. The best selected model(s) may provide insight for developing hypotheses of mechanisms influencing recruitment. Here we consider the influence of a large-scale oceanographic feature, the North Pacific Polar Front, on recruitment of Alaska sablefish (*Anoplopoma fimbria*). Our working hypothesis is that advection of oceanic properties along the Polar Front and associated currents plays a key role in shaping the oceanographic climate of Alaskan waters and, hence, the environment that sablefish encounter during their early life history. As a first step in this investigation, we developed time series of sea surface temperature along the Polar Front mean path. We then integrated this data into the recruitment equations of the sablefish assessment base model. Model selection was based on a multistage hypothesis testing procedure combined with cross-validation and a retrospective analysis of prediction error. The impact of the best model was expressed in terms of increased precision of recruitment estimates and proportional changes in female spawning biomass for both current estimates and in future projections. The best model suggested that colder than average wintertime sea surface temperatures in the central North Pacific represent oceanic conditions that create positive recruitment events for sablefish. The incorporation of this index in the sablefish model provided moderate reduction in unexplained recruitment variability and increased future projections of spawning biomass in the medium term. Based on this result, we developed a conceptual model of three mechanisms that in combination form an ocean domain dynamic synergy (ODDS) which influences sablefish survival through the pelagic early life history stage. Successfully incorporating environmental time series into the sablefish assessment could establish a foundation for future ecosystem-based management and allow for more informed and efficient resource allocation to stakeholders.

Published by Elsevier Ltd.

1. Introduction

Year-class strength is a fundamental driver of fluctuations in stock size for many fish populations and is generally considered to be the abundance of the youngest fish entering a population that can be estimated successfully (Myers, 1998; Maunder and Watters, 2003). Developing reliable estimates of year-class strength, which is also termed recruitment, has been a long-standing problem for fisheries management. The difficulty arises from limited survey or fishery information on the early life stages of the fish. Often direct estimation of early life stages from egg and larval surveys is very limited and standard adult surveys cannot provide estimates of year-class strength until the fish are several years old because the survey does not sample the early juvenile sizes. Therefore, the primary data on these stages are derived from modeling demographic information such as ages and lengths to provide estimates of past recruitment. The uncertainty of these estimates increases toward the beginning and end of a population time series when the demographic data become very limited due to estimation error at advanced ages or no

---

* Corresponding author. Tel.: +1 907 789 6056; fax: +1 907 789 6094.
E-mail address: kalei.shotwell@noaa.gov (S.K. Shotwell).

0967-0645/$ - see front matter Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.dsr2.2012.08.024

information as yet on recently produced year classes (Hanselman et al., 2012). The validity and acceptance of recommendations for future harvests are based on the quality of recruitment estimates. The high uncertainty resulting from the lack of data supporting these estimates usually results in their removal for determining projections of future harvests. If these estimates are actually larger or smaller than average, then catch quotas may be set too low or too high, resulting in unattained yield due to natural mortality or unsustainably high fishing pressure that must inevitably be lowered in the future. This produces an inefficient quota-setting system with unnecessary fluctuations in future catch quotas. Managers run the risk of under- or over-harvesting the species as they react to the inertia of poor information. This is not consistent with optimizing yield (Magnuson-Stevens Fishery Conservation and Management Act, amended 1996).

One potential option to decrease uncertainty in this system is to integrate ecologically plausible environmental time series into a population model (Deriso et al., 2008). Often relationships between recruitment and the environment are evaluated using correlative analyses outside an estimation procedure. Upon re-evaluation with new observations, these relationships do not continue to hold and managers are reluctant to incorporate such environmental time series into harvest recommendations (Myers, 1998). An alternative to simple correlations is to incorporate environmental time series into a statistical catch-at-age analysis where model parameters are estimated simultaneously in a maximum likelihood framework (Maunder and Watters, 2003). In this way, the uncertainty in the environment–recruit relationship and interactions with other data sources may be estimated and conveyed to management. Additionally, environmental influences on species at the center of their geographic distribution may not be as influential or identifiable as for species at their geographic limit (Myers, 1998). The slower growth rates of cooler water species usually extends the duration of life history stages resulting in a potentially greater influence of variability within the physical and biological environment (Field and Ralston, 2005). Environment–recruit relationships developed for stocks at the more extreme edge of their distribution may be more consistent and reliable over time. The caveat of these relationships are the difficulty in identifying the causal forcing factors that influence a given species' survival and then developing proxy environmental time series that represent the appropriate spatial and temporal extent of these factors.

In this study we sample a large-scale oceanographic feature in order to develop environmental indices that represent the spatial and temporal patterns of that feature. These indices are then tested within a population model to determine the approximate location and timing for influencing a given species' recruitment. Improvement in subsequent recruitment estimation may provide insight into developing hypotheses for potential biological mechanisms that influence the species' survival. Our case study is Alaska sablefish (*Anoplopoma fimbria*), a highly valuable commercial groundfish species with extremely high movement rates and an early life history that begins offshore on the Alaskan continental slope. We hypothesize that the North Pacific Polar Front and the associated currents act as a conduit for transporting heat, salt, and nutrients from the western and central North Pacific to Alaska waters. This advection plays a key role in shaping the oceanographic climate of Alaskan waters and may influence the survival, and subsequent recruitment, of sablefish during their early life history.

Adult sablefish are distributed across the North Pacific from northern Mexico to the Bering Sea. Two populations exist within this range based on differences in growth rate, size at maturity, and tagging studies (McDevitt, 1990; Saunders et al., 1996; Kimura et al., 1998). The northern or Alaska sablefish are assessed as a single population in Federal waters off Alaska due to their propensity for large-scale movements (Heifetz and Fujioka, 1991). Adult sablefish in Alaska are typically encountered between 200 and 1000 m along the continental slope, shelf gullies, and deep-sea canyons (Wolotira et al., 1993). In early spring, spawning and egg incubation take place at depth (>300 m). Following hatch, larvae begin to feed and immediately swim to the surface (Mason et al., 1983). Larvae have been sampled in surface waters far from shore (160 km in southeast Alaska to 240 km in the Aleutians) and grow very quickly from 1.2 to 2 mm per day (Wing, 1997; Kendall and Matarese, 1987; Sigler et al., 2001). When larvae are small, diet consists mostly of copepod nauplii and eggs and as they grow diet shifts to mainly copepods and euphausiids (Yang and Nelson, 2000). There is no clear transition from larvae to young-of-the-year (YOY) or age-0 sablefish. However, large, pigmented pectoral fins are a diagnostic feature of larvae as they grow and both stages appear to be obligate surface dwellers (neustonic) as they drift to shore (Kendall and Matarese, 1987). Juvenile sablefish may also exhibit some thermal intolerance to very cold water (Sogard and Olla, 1998). Typically, by the end of the summer YOY sablefish reach nearshore bays, which serve as overwinter habitat until the following summer when juveniles begin movement to their adult habitat, arriving within three to four years (Rutecki and Varosi, 1997). The long-distance dispersal to nearshore habitat and rapid growth requirements throughout this pelagic early life history stage suggest that YOY sablefish may be more susceptible to the influence of large-scale oceanographic features.

The trans-Pacific Subarctic Gyre dominates the large-scale ocean circulation in Alaska waters. It is comprised of two cells termed the Western and Eastern Subarctic Gyres, WSAG and ESAG, respectively. The demarcation line between the WSAG and the ESAG is ill-defined yet believed to be approximated between the 170°E and 180°E meridians (Longhurst, 2007). Three main currents dominate the counter-clockwise flow of the ESAG, also termed the Alaska Gyre. Eastward transport along the southern limb is achieved by the North Pacific Current, which bifurcates into two broad currents as it reaches the American continent near Vancouver Island, Canada (Tomczak and Godfrey, 1994; Longhurst, 2007). From this point, the poleward limb of the Alaska gyre consists of the broad (300 km) Alaska Current which flows slowly (5–15 cm/s) along the northeastern and northern Gulf of Alaska (GOA) until its transformation near Prince William Sound (150°W) to the southwestward-flowing Alaskan Stream. This narrow (100 km), swift (100 cm/s) current continues westward along the Alaska Peninsula and Aleutian Islands until it gradually weakens west of 180°W (Weingartner, 2005). Along most of the Alaskan continental shelf, these main currents are paralleled by the inshore Alaska Coastal Current (ACC). This is a narrow, wind- and buoyancy-driven current that is mediated by downwelling-favorable winds and freshwater runoff (Weingartner et al., 2002, 2005). The circulation strength of the Subarctic Gyre and bifurcation latitude for the North Pacific Current are governed by the location and intensity of the Aleutian Low (Weingartner et al., 2009), which is the prominent geophysical feature associated with Alaska climate (Mundy and Olsson, 2005). Low-pressure storm systems making up the Aleutian Low are often generated in the western and central North Pacific and strengthen as they propagate eastward into Alaska waters (Weingartner, 2005).

The Subarctic–Subtropical Transition Zone separates the Subarctic Gyre from the warmer Subtropical Gyre and the northern and southern boundaries of this zone have the character of frontal regions (Roden, 1991). Ocean fronts are relatively narrow zones of enhanced horizontal gradients (e.g. temperature, salinity, etc.) that

Download English Version:

https://daneshyari.com/en/article/4536350

Download Persian Version:

https://daneshyari.com/article/4536350

Daneshyari.com