Deep-Sea Research II ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Deep-Sea Research II

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

Feeding ecology of age-0 walleye pollock (*Gadus chalcogramma*) and Pacific cod (*Gadus macrocephalus*) in the southeastern Bering Sea

Wesley W. Strasburger [a,b,*], Nicola Hillgruber [c,d], Alexei I. Pinchuk [c], Franz J. Mueter [c]

[a] Ted Stephens Marine Research Institute, Alaska Fisheries Science Center, NMFS, NOAA, 17109 Point Lena Loop Rd., Juneau, AK 99801, USA
[b] Department of Commerce, 17109 Point Lena Loop Rd., Juneau, AK 99801, USA
[c] School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 17101 Point Lena Loop Rd., Juneau, AK 99801, USA
[d] Thünen Institute of Fisheries Ecology, Wulfsdorfer Weg 204, 22926 Ahrensburg, Germany

ARTICLE INFO

Keywords:
Walleye pollock
Pacific cod
Dietary composition
Feeding success
Southeastern Bering Sea
Larvae
Juveniles

ABSTRACT

Walleye pollock (*Gadus chalcogramma*) and Pacific cod (*Gadus macrocephalus*) are of particular economic and ecological importance in the southeastern Bering Sea. The spatial and temporal overlap of early life stages of both species may explain their strongly correlated recruitment trends. Pelagic larvae and juveniles were collected during four research cruises in May, July and September of 2008, an exceptionally cold year, and their stomach contents were examined. Feeding success and diet composition of walleye pollock and Pacific cod were consistently different in spring, summer, and fall. Pacific cod larvae and juveniles always consumed larger and progressively fewer prey items per stomach than walleye pollock; this difference was particularly pronounced in the fall. Our data suggest that co-occurring early life stages of walleye pollock and Pacific cod were dividing prey resources rather than competing for them, at least during the exceptionally cold conditions in 2008 in the southeastern Bering Sea.

1. Introduction

Walleye pollock (*Gadus chalcogramma*), hereafter called pollock, and Pacific cod (*Gadus macrocephalus*) are two of the largest and most valuable fisheries in the Bering Sea, with an annual harvest of 0.48–1.40 million metric tons (Ianelli et al., 2011) for pollock in the southeastern Bering Sea (SEBS) and 120,000–183,000 metric tons for Pacific cod in the eastern Bering Sea over the past decade (Thompson et al., 2011). These species are of ecological importance within the SEBS ecosystem (Aydin and Mueter, 2007), where they serve as prey for seabirds (Decker and Hunt, 1996), marine mammals (Sinclair et al., 1994) and other fishes, including older age-classes of pollock (Bailey, 1989). Both species are predatory, pollock consumes a variety of forage fishes (Coyle et al., 2011), while Pacific cod consume large amounts of commercially targeted crab species (Livingston, 1989; Urban, 2012). Thus, pollock and Pacific cod play a central role in the food web of the SEBS. A better understanding of the ecology of these two species and their interactions with different ecosystem components would enhance our ability to successfully model these populations via changing prey and prey quality as they are mediated by changing climatic conditions.

In the SEBS, pollock and Pacific cod exhibit similarities in early life history patterns, spatial distribution, and subsequent recruitment success (Bacheler et al., 2010; Duffy-Anderson et al., 2006; Hurst et al., 2012; Matarese et al., 2003; Mueter et al., 2011). Both species spawn from January to April (Bacheler et al., 2010; Shimada and Kimura, 1994) in relatively deep waters over the continental shelf, along the Alaska Peninsula, and near the Pribilof Islands (Bacheler et al., 2010; Fritz et al., 1993). Pollock eggs tend to be slightly positively buoyant and pelagic, while Pacific cod eggs tend to be negatively buoyant and demersal (Dunn and Materese, 1987). Post-hatch, both species rise to the epi-pelagic layer and share a similar horizontal distribution (Duffy-Anderson et al., 2006; Matarese et al., 2003). Specifically, both species have larval abundance maxima in the SEBS along the Alaska Peninsula and Aleutian Islands, particularly in and around Unimak Pass, as well as north of the Pribilof Islands (Matarese et al., 2003). During late spring and early summer, pelagic larvae and juveniles are concentrated in the upper mixed layer (10–40 m). By the fall, juvenile pollock disperse throughout the water column at standard lengths (SL) > 40 mm, while Pacific cod juveniles begin to settle out to a demersal lifestyle earlier in the year at > 35 mm SL (Bailey, 1989; Blackburn and Jackson, 1982; Ciannelli et al., 1998; Dunn and Materese, 1987; Nishiyama et al., 1986; Rugen and Materese, 1988).

* Corresponding author at: Ted Stephens Marine Research Institute, Alaska Fisheries Science Center, NMFS, NOAA, 17109 Point Lena Loop Rd., Juneau, AK 99801, USA. Tel.: +1 907 789 6009; fax: +1 907 789 6408.
E-mail addresses: wes.strasburger@noaa.gov (W.W. Strasburger), nhillgruber@alaska.edu (N. Hillgruber), aipinchuk@alaska.edu (A.I. Pinchuk), fmueter@alaska.edu (F.J. Mueter).

0967-0645/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.dsr2.2013.10.007

Please cite this article as: Strasburger, W.W., et al., Feeding ecology of age-0 walleye pollock (*Gadus chalcogramma*) and Pacific cod (*Gadus macrocephalus*) in the southeastern Bering Sea. Deep-Sea Res. II (2013), http://dx.doi.org/10.1016/j.dsr2.2013.10.007

Due to the spatial and temporal overlap of early pelagic life stages, and because of similarities in body size and shape, it is reasonable to assume that pollock and Pacific cod exploit similar prey resources, resulting in potential dietary overlap and the possibility for competition. Numerous studies have been conducted on the diet of larval and juvenile pollock in the SEBS, most of these diet studies focused either on larval fish in spring (Hillgruber et al., 1995; Nishiyama et al., 1986; Porter et al., 2005) or on juvenile stages later in the fall (Brodeur et al., 2000; Coyle et al., 2008, 2011; Moss et al., 2009; Schabetsberger et al., 2000, 2003). Published information regarding feeding success and dietary patterns of age-0 Pacific cod in the SEBS is limited, and is only available for juveniles later in their first year (Lee, 1985). Knowledge of early life stage feeding patterns in both species is of importance to better understand recruitment success, particularly in light of changing environmental conditions in the Arctic and sub-Arctic (Hunt et al., 2011).

The SEBS experiences oscillating temperature ranges (Mueter and Litzow, 2008; Overland and Stabeno, 2004) marked by variable sea ice conditions (i.e., extent, thickness, and time of retreat), water temperature, and stratification in this region (Stabeno et al., 2012). These changes in the physical environment influence the timing, duration, and magnitude of the spring bloom, as well as recruitment success, growth, and nutritional condition of the zooplankton community (Hunt and Stabeno, 2002; Hunt et al., 2002, 2011; Walsh and McRoy, 1986); which in turn affects larval and juvenile pollock and Pacific cod relying on the zooplankton community for prey (Coyle et al., 2011; Hunt et al., 2011; Moss et al., 2009). Seasonal sampling for this study was conducted in 2008, a year characterized by heavy sea ice cover, late ice retreat, and cold temperatures (Stabeno et al., 2012). The overall goal of this study was to examine and compare feeding success and dietary composition of both pollock and Pacific cod during their first year, and during cold conditions in the SEBS. The underlying hypothesis was that larvae and juveniles of these two species, which share ecological preferences, may feed on similar prey items and during cold conditions may both primarily consume large prey taxa (*Calanus marshallae/glacialis*, hereafter referred to as *Calanus* spp. and juvenile *Thysanoessa* spp.) which in turn may contribute to coincident strong cohorts. To test this hypothesis we

1) compared patterns of dietary composition of larvae and juveniles of these two gadoid species, and
2) compared measures of feeding success and dietary composition from the exceptionally cold growing season in 2008 to previous studies to evaluate environmental effects on recruitment potential.

2. Methods

2.1. Sample collection

This study was based on samples of early life history stages of pollock and Pacific cod that were acquired opportunistically from multiple projects (Table 1). The goal of sample acquisition was to obtain a good seasonal coverage of age-0 larval and juvenile stages of both species. Early life stages were obtained from sampling efforts in spring (May), summer (July), and fall (September) of 2008.

In spring of 2008, pre-flexion larvae were collected by the Alaska Fisheries Science Center, National Marine Fisheries Service participating in the Bering Sea Project (AFSC, NMFS; Fig. 1A). Fish larvae were collected with oblique 60 cm diameter Bongo tows (Table 1). Sampling was conducted 24 h a day; however, only two stations included in this study were sampled after dusk. After retrieval of the sampling gear, all fish larvae were removed from the codend and preserved in 5% buffered formalin-seawater solution. Six pollock and 8 Pacific cod larvae in these collections still retained a yolk-sac and were therefore considered to be not yet

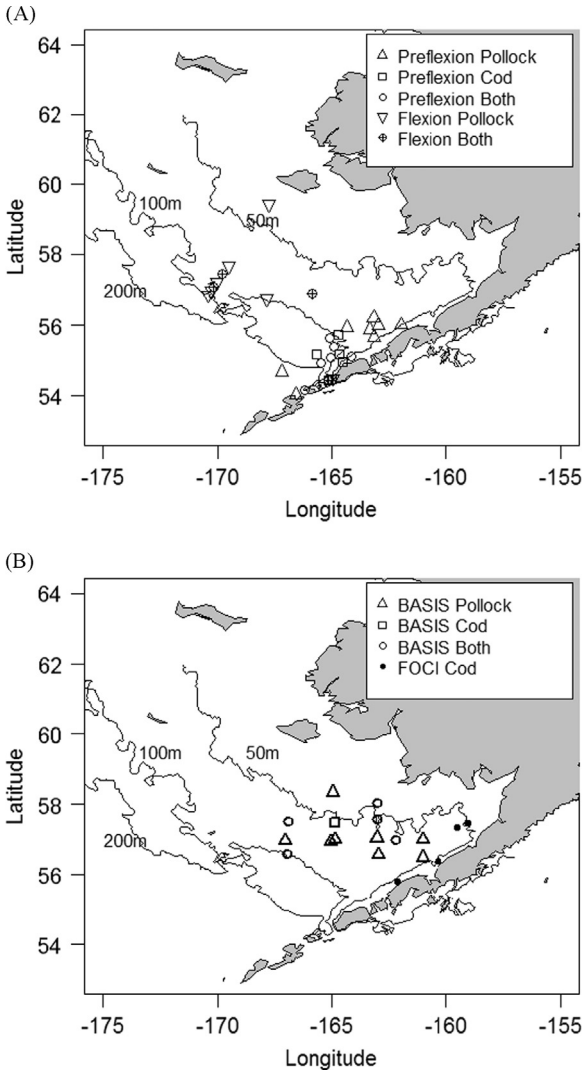

Fig. 1. Sampling sites for walleye pollock and Pacific cod used in this study. (A) Spring and mid-summer samples and (B) fall samples. See Table 1 for cruise details.

Table 1
Sample size (*N*) of walleye pollock and Pacific cod collected in 2008 by season (spring, summer, and fall), agency and/or project, sample gear, and mesh size. FOCI: Fisheries Oceanography Coordinated Investigations; NOAA AFSC: National Oceanic and Atmospheric Administration, Alaska Fisheries Science Center; BEST/BSIERP SFOS: Bering Ecosystem Studies/Bering Sea Integrated Ecosystem Research Project, School of Fisheries and Ocean Sciences; BASIS: Bering-Aleutian Salmon International Survey.

Season	Project/Agency	Gear	Mesh	Sample date range	Number of hauls (# of hauls with both pollock and cod)	Walleye pollock, *N* (size range, mm)	Pacific cod, *N* (size range, mm)
Spring	FOCI, NOAA AFSC	Bongo	500 μm	May 12–28	21 (7)	17 (3.2–7.4)	17 (3.0–7.6)
Summer	BEST-BSIERP SFOS	MOCNESS	500 μm	July 3–31	11 (4)	11 (4.4–22)	4 (9.1–16.4)
Fall	BASIS, NOAA AFSC	Rope Trawl	120 mm	September 9–27	14 (5)	13 (36.2–88)	6 (52.8–87)
Fall	FOCI, NOAA AFSC	Beam Trawl	7.0 mm	September 10–20	4 (0)	–	4 (65–87.2)

Please cite this article as: Strasburger, W.W., et al., Feeding ecology of age-0 walleye pollock (*Gadus chalcogramma*) and Pacific cod (*Gadus macrocephalus*) in the southeastern Bering Sea. Deep-Sea Res. II (2013), http://dx.doi.org/10.1016/j.dsr2.2013.10.007