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Habitat quality of the coastal southeastern Bering Sea for juvenile flatfishes from the relationships between diet, body condition and prey availability

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ABSTRACT

The distribution and body condition of juvenile northern rock sole (NRS), *Lepidopsetta polyxystra*, and yellowfin sole (YFS), *Limanda aspera*, were studied in relation to prey availability across the coastal shelf at the Alaska Peninsula boundary of the eastern Bering Sea (EBS) to assess spatial variability in habitat quality. Juveniles of ≤20 cm and adults of ≥30 cm total length were collected from bottom trawl catch samples at stations located 10 to 120 km from the Alaska Peninsula coast, and in bottom depths of 28 to 85 m. Stomach contents and stable isotopes of carbon and nitrogen from muscle tissue were analyzed to describe diet composition. The quantity and quality of prey did not significantly affect the distribution of juvenile NRS and YFS. Spatial mismatch between the diet composition and the infauna prey assemblage suggested that prey availability was not limiting across the area, allowing fish to select for prey, presumably to maximize net energy gain. The body condition of juvenile NRS was higher in the eastern section of the area (Bristol Bay) – where they shared spatial and dietary niches with juvenile YFS, than in the west section (Unimak Island) where juvenile YFS were largely absent. A difference in body condition suggests that habitat quality may be higher in Bristol Bay. For NRS, stomach contents and stable isotopes in muscle tissue indicated an ontogenetic diet shift from amphipods to polychaetes from juvenile to adult stages. In contrast, for YFS, amphipods seemed to remain the primary prey and polychaetes the least important prey from juvenile to adult stage. Given that the high prey availability found in this south coastal area of EBS extends to areas across the EBS shelf, favorable habitat for juvenile flatfishes should be extensive. However, much of this potential juvenile habitat is underutilized by NRS, which were mainly limited to Bristol Bay and the Alaska Peninsula, whereas YFS did extend north over 500 km from Bristol Bay along the inner shelf domain (≤50 m deep). Abiotic factors, particularly ocean currents and water temperature, may be more significant than prey availability in the spatial distribution of juveniles. Thus, changes in the hydrographic and thermal regime of the EBS are likely to impact juvenile flatfish distribution and habitat productivity.

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1. Introduction

The eastern Bering Sea (EBS) ecosystem is the setting for the most productive fisheries in the United States (NOAA Fisheries, 2013; National Research Council, 1996). Flatfishes dominate the fish biomass in the EBS ecosystem, the two most abundant of which are yellowfin sole (YFS), *Limanda aspera*, and northern rock sole (NRS), *Lepidopsetta polyxystra*. Both are commercially harvested, with the YFS fishery being the largest flatfish fishery in the world (Wilderbuer et al., 2013). YFS and NRS have a similar size range, overlapping distributions across most of the EBS shelf (≤110 m), and both prey mainly on polychaetes, amphipods, and clams (Yeung et al., 2013). The spawning and feeding distributions of YFS and NRS vary temporally and spatially. YFS are known to overwinter near the shelf margin and migrate onto the inner shelf in April–May for spawning and feeding throughout the spring and summer (Wilderbuer et al., 2013), whereas NRS spawn earlier, in December–March (Wilderbuer and Nichol, 2012).

Climate change is altering the Bering Sea ecosystem (Grebmeier et al., 2006; Sigler et al., 2011; Stabeno et al., 2012b), where currents, sea ice, and winds control primary productivity and trophic structure (Stabeno et al., 2005; Stabeno et al., 2010). The EBS shelf is divided into the inner, middle, and outer biogeographical domains by oceanographic fronts associated with the 50, 100, and 200 m isobaths (Coachman, 1986). A prominent oceanographic feature is the “cold pool” - the tongue of <2 °C bottom water in the middle domain (50–100 m depth) that tends to exclude cold-intolerant demersal species (Stabeno et al., 2012b). The predicted long-term trend of warming ocean temperature, diminishing sea ice, and shrinking cold pool is

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expected to impact ecosystem functions and the distributions of marine species in the EBS (Kotwicki and Lauth, 2013; Stabeno et al., 2012a; Stevenson and Lauth, 2012), prompting an impetus to understand the population ecology of key species in order to gauge the potential impacts.

The quantity and quality of habitat are critical to the fitness of juvenile fish and ultimately to fisheries recruitment. It is therefore necessary to protect juvenile habitats as anthropogenic and climate influences shift the seascape (Beck et al., 2001). The spatial distribution of a species is often used as the basis for delineating its habitat in the absence of other ecological information. The distribution of YFS and NRS in the EBS is drawn from a large-scale annual bottom trawl survey of groundfish stocks (Lauth and Connor, 2014). Early-juvenile flatfishes may be under-sampled by the survey because the trawl net has relatively large mesh, and the survey stations lie deeper and further offshore than where they generally inhabit (MacPherson and Duarte, 1991; Nichol, 1997). Regardless, the National Marine Fisheries Service bottom trawl time series in the EBS is the best available information for inferring the locations of juvenile flatfish habitat regionally.

Hydrodynamic modeling has suggested that NRS larvae may actually settle hundreds of kilometers from the coast (Cooper et al., 2013). Larval transport likely follows a major circulation pathway – west along the southern side of the Alaska Peninsula with the Alaska Coastal Current, through Unimak Pass into the Bering Sea, then northeast along the opposite side of the Alaska Peninsula with the Bering Coastal Current, and eventually turning northwest in Bristol Bay towards Nunivak Island (Fig. 1) (Cooper et al., 2014; Cooper et al., 2013; Lanksbury et al., 2007). NRS presumably move inshore after settlement (Cooper et al., 2014).

There is very little information on the location and characteristics of juvenile flatfish habitat in the EBS. Juvenile NRS habitat has been studied in the Gulf of Alaska, but mainly in an experimental context at nearshore sites on a small, local scale (Abookire and Norcross, 1998). Recently, there has also been effort to delineate the regional distribution of age-0 and age-1 NRS with beam trawl studies (Cooper et al., 2014; Cooper et al., 2013), and of juvenile YFS of ≤24 cm total length from bottom trawl surveys (Bartolino et al., 2010). Juvenile NRS were found to be concentrated near Unimak Island at the Alaska Peninsula boundary of the coastal south-EBS, and further north between Nunivak Island and Cape Newenham. Juvenile YFS were found to be concentrated in nearshore waters between Nunivak Island and Bristol Bay.

Fish habitat models are typically based on correlating habitat parameters and fish density. Standard abiotic variables, such as temperature and salinity, are the main building blocks of habitat models, in large part because of the time- and cost-effectiveness of collecting such data. However, models containing only abiotic variables often limit their ability to explain the observed variability in fish density, and do not provide a measure of habitat quality (Cooper et al., 2014; Le Pape et al., 2007; Trimoreau et al., 2013). Substrate type is an example of an abiotic variable often found to be significantly correlated with yet not adequately explain flatfish distributions (Abookire and Norcross, 1998; Amezcua and Nash, 2001; Bartolino et al., 2010; McConnaughey and Smith, 2000; Moles and Norcross, 1995; Rooper et al., 2005).

It is increasingly evident that large scale (≥100 km^2) studies of the correlation between abiotic habitat variables with fish distribution are not yielding new insights into ecological processes. Biotic habitat variables that drive not only fish distribution, but growth and survival at

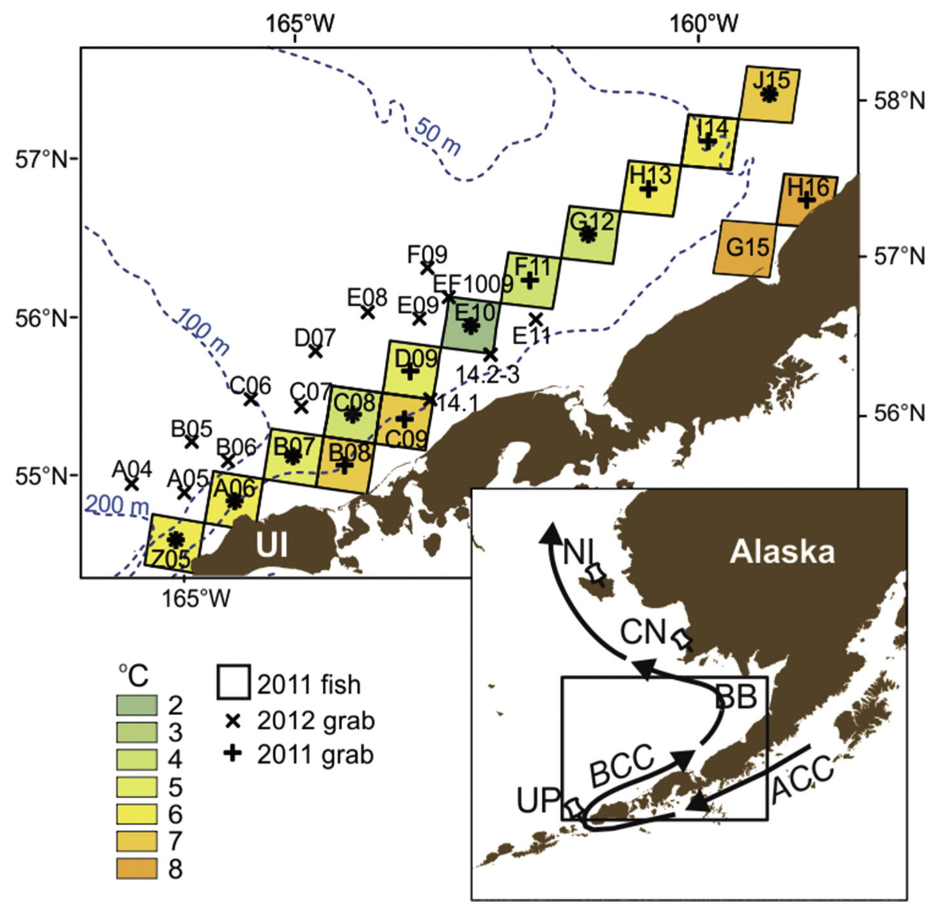

Fig. 1. The study area (upper map) showing the bottom trawl grid cells from which fish samples were collected (near center of cell) in 2011, and the locations of benthic grab samples in 2011 and 2012. Bottom temperature at the sampling stations in 2011 is depicted on a color scale. The relative location of the study area is delineated in the eastern Bering Sea region (lower map), where the mean circulation is indicated (BCC – Bering Coastal Current; ACC - Alaska Coastal Current; UI – Unimak Island; UP – Unimak Pass; BB – Bristol Bay; CN – Cape Newenham; NI – Nunivak Island).