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Variations in age-0 pollock distribution among eastern Bering Sea nursery areas: A comparative study through acoustic indices

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Abstract

Cohort abundance of walleye pollock (*Theragra chalcogramma*) is subject to strong interannual variation in the eastern Bering Sea, and this variation is known to be determined largely at the age-0 stage. We estimated the spatial distributions and densities of age-0 walleye pollock in five nursery areas around the eastern Bering shelf in three successive years (1997–1999) from acoustic survey data. Concurrently, we calculated estimates of the spatial distribution of euphausiids, a major prey of age-0 walleye pollock, and estimates of spatial overlap of groundfish predators with the age-0 walleye pollock. The analyses showed that all nursery areas had low densities of age-0 walleye pollock in 1997, which ultimately produced the weakest adult year-class. In the intermediate year of 1998, age-0 densities were low to medium, and in 1999, which produced the strongest of the three adult year-classes, all nursery areas had medium to high age-0 walleye pollock densities. Euphausiid distributions had a consistently positive spatial relationship with age-0 walleye pollock. Groundfish predator density ratios were positively related to age-0 walleye pollock density when age-0 walleye pollock were displaced relatively northward. Our results suggest that abundance of age-0 walleye pollock, and hence of adult cohorts in the eastern Bering Sea, can be predictable from a concise set of indicators: the densities of age-0 walleye pollock at nursery areas in mid- to late-summer, their spatial relationship to euphausiids and groundfish predators, and the latitudinal trend of their distributions. The 3 years 1997–1999 had significant differences of physical conditions in the eastern Bering Sea, and represent an advantageous framework for testing these hypotheses.

Keywords: Walleye pollock; Euphausiid; Nursery areas; Echo survey; Eastern Bering Sea

1. Introduction

Walleye pollock (*Theragra chalcogramma*) is a key species of the Bering Sea food web and the target of important commercial fisheries (Springer, 1992; NRC, 1996). Cohort abundance of walleye pollock populations is subject to strong interannual variation (Ianelli et al., 2004), and a major research objective has been to address the predictability of this variation (Ohtani and Azumaya, 1995; Quinn and Niebauer, 1995; Swartzman et al., 2002). Previous studies have found that cohort abundance of a walleye pollock stock is determined primarily through conditions affecting the pre-recruit, juvenile

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stages (Bailey et al., 1996; Bailey, 2000; Hunt et al., 2002a). Recent investigations have therefore focused on regions of the Bering Sea where juvenile walleye pollock aggregate and grow through their first year (Brodeur and Wilson, 1999; Swartzman et al., 2002, 2005).

The Pribilof Islands, near the Bering Sea shelf edge, have been recognized as a center of abundance of age-0 walleye pollock (Traynor and Smith, 1996; Nishimura et al., 1996), and described as a walleye pollock 'nursery' (Brodeur, 1998; Brodeur et al., 2002a; Macklin et al., 2002; Swartzman et al., 2002). Important concentrations of age-0 walleye pollock likewise have been observed at sampling stations on the inner shelf of the eastern Bering Sea (Coyle and Pinchuk, 2002a). The Pribilof Islands and inner-shelf areas were surveyed in mid- to late-summer of 3 consecutive years (1997–1999) during, respectively, the Southeast Bering Sea Carrying Capacity (SEBSCC) and Inner Front projects, to investigate processes of the southeast Bering pelagic ecosystem (Macklin et al., 2002). Swartzman et al. (2005) concluded that age-0 walleye pollock densities were variable, but generally of the same magnitude among Pribilof Islands and Inner Front areas in 1997–1999. In this paper, we hypothesize that similar densities in different areas are characterized by similar spatial relationships of the age-0 walleye pollock with their prey and predators.

Both the SEBSCC (Pribilof Islands) and Inner Front projects included two-frequency acoustic data collection on repeated transects (Swartzman, 2004). We utilize these acoustic data to delineate and quantify spatial distributions of age-0 walleye pollock in comparing the different areas surveyed. The 3-year series of parallel SEBSCC and Inner Front surveys are not long for the purpose of a comparative study, but the period of 1997–1999 was significant for its strong environmental changes in the eastern Bering Sea. Summer sea-surface temperatures were unusually high in 1997 (Napp and Hunt, 2001), and low in 1999 with heavy sea-ice cover in late spring (Stabeno et al., 2001). Bottom water temperatures were above average in 1998 (Stabeno et al., 2001). A coccolithophore bloom was recorded in the eastern Bering Sea for the first time in 1997 (Sukhanova and Flint, 1998; Stockwell et al., 2001), and recurred each year until 2001 (Hunt, 2004). Conditions associated with coccolithophore blooms may present inferior nutritional quality for zooplankton (Nejstgaard et al., 1995; Hunt et al., 1999). A climatic regime shift (Hare and Mantua, 2000), with accompanying shifts in species composition and abundance in the Northeastern Pacific, appears to have happened around 1998 or 1999 (Ingraham et al., 1998; McFarlane et al., 2000). The Oscillating Control Hypothesis (Hunt et al., 2002a; Hunt and Stabeno, 2002) proposes, in part, that during cold periods, the survival of juvenile walleye pollock will be bottom-up controlled by decreased production of copepods (Huntley and Lopez, 1992), which are a food source for euphausiids (Ohman, 1984) as well as for juvenile walleye pollock (Schabetsberger et al., 2000; Brodeur et al., 2000). During warm periods when zooplankton are plentiful, the Oscillating Control Hypothesis predicts that juvenile walleye pollock will be top-down controlled by adult walleye pollock predation, to the extent that the adult population experienced large year-classes through previously favorable conditions (Hunt et al., 2002a; Hunt and Stabeno, 2002).

Whichever control dominates in a given year, juvenile fish will seek to maintain feeding satiation and minimize energy expenditure while avoiding predators. For the SEBSCC and Inner Front survey transects, we analyzed the acoustically determined densities and spatial distributions of age-0 walleye pollock in relation to: the acoustically determined distributions of euphausiids (a major zooplankton prey of age-0 walleye pollock), the distributions of groundfish predators, the frontal zones, and the relative northward displacement of the age-0 walleye pollock biomass. Frontal zones refer to the hydrographic structuring of the water column that separates tidally mixed nearshore waters from thermally stratified offshore zones (Stabeno et al., 1999). Such hydrographic structuring can create zones of increased environmental heterogeneity (Sournia, 1994) and concentrated nutrient availability (Coyle and Pinchuk, 2002a; Flint et al., 2002). Nearshore, front, and offshore zones in a nursery area may represent distinct habitat conditions for age-0 walleye pollock (Ciannelli et al., 2002; Swartzman et al., 2002). The relative northward displacement of age-0 walleye pollock biomass may serve as a potential indicator for effects of current transport or water temperature (cf. Wespestad et al., 2000; Overland and Stabeno, 2004). The estimated densities of age-0 walleye pollock in eastern Bering Sea survey areas varied by a factor of more than five between the cohorts of 1997–1999 (Swartzman et al., 2005), providing a useful basis for characterizing conditions that may regulate walleye pollock survival.