Journal of Experimental Marine Biology and Ecology 446 (2013) 311–319

Contents lists available at SciVerse ScienceDirect

Journal of Experimental Marine Biology and Ecology

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

Polychaete worm tubes modify juvenile northern rock sole *Lepidopsetta polyxystra* depth distribution in Kodiak nurseries

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ARTICLE INFO

Article history:
Received 29 January 2013
Received in revised form 28 May 2013
Accepted 29 May 2013
Available online 29 June 2013

Keywords:
Biogenic habitat
Juvenile flatfish
Refuge
Sabellides sibirica
Video sled

ABSTRACT

We have observed inter-annual variability in the depth distribution of juvenile northern rock sole *Lepidopsetta polyxystra* on their nursery grounds around Kodiak Island, Alaska. This study evaluates whether this variability is a response to inter-annual changes in the availability of habitat created by polychaete tubes; principally *Sabellides sibirica*. We suspect that worm tubes constitute an alternative refuge and/or feeding habitat for juvenile flatfish. Accordingly, we hypothesized that during years of low worm abundance, fish would concentrate in the shallows (<10 m depth) where they find refuge from predation, but would move to greater depths (>15 m, where the worms occur) during years when the worms were abundant. Using data on worm abundance and fish density over 5 yr, we tested this hypothesis at 2 Kodiak nursery embayments. Whether worms were abundant in a given year or embayment had no influence on overall fish abundance, however, worm abundance did influence juvenile flatfish depth distributions. At Holiday Beach, where worms tended to be scarce, fish were typically concentrated in shallow water. However, during the 1 year when worms were abundant, fish were concentrated in deeper water. At Pillar Creek Cove, where worms are more regularly found, fish tended to concentrate in deeper water, the exception being the one year when worms were nearly absent. Regression analysis for both sites and all years indicated that the percent of fish occupying shallow water (<10 m) decreased with increasing worm abundance. When worms were prevalent, fish were most commonly found on bottom with sparse to moderate worm cover, but avoided bottom where the worms were so dense as to form a 'turf'. These results demonstrate that the geographic and inter-annual variation in worm tube abundance has significant influence over the distribution of juvenile northern rock sole.

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1. Introduction

The depth range over which a marine species, or life-stage, occurs is perhaps one of the most fundamental descriptors of its habitat. It has been widely observed that small fishes and crustaceans often aggregate in shallow water. The benefits of shallow water occupancy for juveniles are both physiological and ecological. On the physiological side, higher ambient temperature and abundant food in shallow water can accelerate growth (Ryer et al., 2012; Yamashita et al., 2001), hastening the point at which juveniles reach size-refuge from predators, potentially allowing greater survival potential both in the shallows and when they migrate to the adult habitat (Blundon and Kennedy, 1982). On the ecological side, aggregation of juvenile fishes and crustaceans in shallow waters is often attributed to lower predation rates; the 'Shallow Water Refuge Hypothesis' (sensu Baker and Sheaves, 2007). Lower predatory threat in shallow water may not only increase survival (Linehan et al., 2001; Manderson et al., 2004; Ryer et al., 2010a), but increase growth, as juveniles can decrease vigilance and devote more time to feeding (Ryer and Hurst, 2008). Further, in many systems shallow water and structured habitats go hand-in-hand; seagrasses, marshes, mangroves, and littoral vegetation in lakes and rivers (Crowder and Cooper, 1982). In addition to foraging opportunities, the habitat created by physical structure such as vegetation provides refuge from predation by interfering with the detection and pursuit of prey (Bartholomew et al., 2000; Ryer et al., 2004).

Yet, many soft bottom communities are devoid of rooted vegetation, and a wide variety of other structures, less conspicuous to the human eye, provide habitat for both juveniles and adults of many fish species (Auster et al., 1996; Thrush et al., 2002). Winter flounder *Pseudopleuronectes americanus* initially recruit to muddy sediments, but by the time they reach 55 mm total length (TL) they often associate with drift algae, woody debris, and shells (Howell et al., 1999; Sogard and Able, 1991; Stoner et al., 2001). Polychaete worm tubes that project from the sediment surface can also provide juvenile fish habitat. On the northeast Atlantic continental shelf, mats composed of *Diopatra cuprea* and *Asabellides occulata* tubes, host twice as many fish as adjacent bare sand bottom (Diaz et al., 2003, 2004). Similarly, in intertidal nurseries along the Belgian coast, juvenile plaice *Pleuronectes platessa* are three times more abundant in 'reefs' built

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0022-0981/$ – see front matter. Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.jembe.2013.05.026

by the polychaete *Lanice conchilega*, than on adjacent bare sand bottom (Rabaut et al., 2010).

In the North Pacific, juveniles of many flatfish species utilize shallow water nursery areas (Minami and Tanaka, 1992). Around Kodiak Island, Alaska, the summer juvenile flatfish assemblage utilizing shallow water embayments is dominated by northern rock sole, *Lepidopsetta polyxystra* (~90% of individuals), as well as lesser numbers of Pacific halibut, *Hippoglossus stenolepis*, and English sole, *Pleuronectes vetulus* (Ryer et al., 2010a, 2012) Northern rock sole recruit to shallow water during the spring and early summer at approximately 15–30 mm TL, and leave for deeper water during the early fall (September–October) having attained 50–80 mm TL (Hurst and Abookire, 2006). During summer, the highest densities of juveniles occur at depths less than 30 m (Hurst et al., 2007; Ryer et al., 2012; Stoner et al., 2007). Flatfish habitat has typically been characterized by physical factors, such as depth, temperature, salinity, sediment grain size and organic content, which influence benthic prey abundance (Abookire and Norcross, 1998; Stoner and Abookire, 2002). Juvenile northern rock sole (hereafter rock sole) demonstrate a preference for silty-sand sediments, with newly settled individuals, in particular, demonstrating a preference for fine sediments that allow burial (Stoner and Abookire, 2002).

However, like many other juvenile fishes, juvenile rock sole also demonstrate preference for emergent structures associated with sedimentary bottoms (Stoner and Titgen, 2003). Stoner et al. (2007) suggested that the presence of the tube building polychaetes, since identified as the ampharetid *Sabellides sibirica* (S. Jewett, University of Alaska Fairbanks, personal communication), influences fish distribution. Juvenile rock sole were most common in sparse to moderate and/or patchy worm coverage, at depths of >15 m. Yet in 2004, worms were largely absent and juveniles tended to be more concentrated in the shallows (<10 m), where predation was lower (Ryer et al., 2010a). Thus, in years when worms are abundant, we suspect that fish may be faced with a trade off; choosing to stay in the shallows, their default means of mitigating predation risk, or moving to greater depth where they can occupy the worm tube habitat. The benefits of associating with worm tubes may be 2 fold; 1) juvenile rock sole consume the worms (Knoth et al., in review), and 2) the worm tubes create a structurally complex habitat that provides juveniles with predation refuge; an alternative to shallow water.

In this study we examine the influence of *S. sibirica* distribution and abundance upon the distribution of juvenile flatfish in 2 Kodiak Island nursery embayments, utilizing data from 5 yr, during which the abundance of *S. sibirica* varied considerably both between years and between study sites. We specifically test the hypothesis that juvenile rock sole reside in shallow water when worm tubes are absent, but shift to deeper water, in association with the worms when worms are prevalent.

2. Materials and methods

2.1. Study sites

The 2 sites are located in coastal waters of Kodiak Island, Alaska (Fig. 1); Holiday Beach (57° 41′ N, 152° 27′ W) and Pillar Creek Cove (57° 49′ N, 152° 25′ W). These 2 sites have been the focus of prior studies examining the recruitment, growth, habitat and ecology of juvenile North Pacific flatfishes (Hurst and Abookire, 2006; Hurst et al., 2007; Ryer et al., 2007, 2010a, 2012; Stoner et al., 2007). Gently sloping bottoms characterize both sites, with coarse sands at depths of <5 m transitioning to silty/muddy sand at depths of >30 m (Stoner et al., 2007). With an area of approximately 123 ha, 1.4 km separates the 5 and 30 m MLLW (mean lower low water) depth contours at Holiday Beach. Pillar Creek Cove comprises approximately 30 ha, with 0.6 km between the 5 and 30 m depths. Summer water temperatures are comparable between sites, ranging from 6 to 11 °C, with bottom water at depths of <10 m generally 1 or 2 °C warmer than bottom water at >20 m depth. At both sites salinity ranges from 30 to 32. The principle physical difference between the 2 sites is wave exposure. With a more easterly exposure, wave action from the Gulf of Alaska is frequently greater at Holiday beach, resulting in bottom disturbance, manifest by the formation of sand waves and ripples (Stoner et al., 2007) as well as re-suspension of fine particles that increase turbidity.

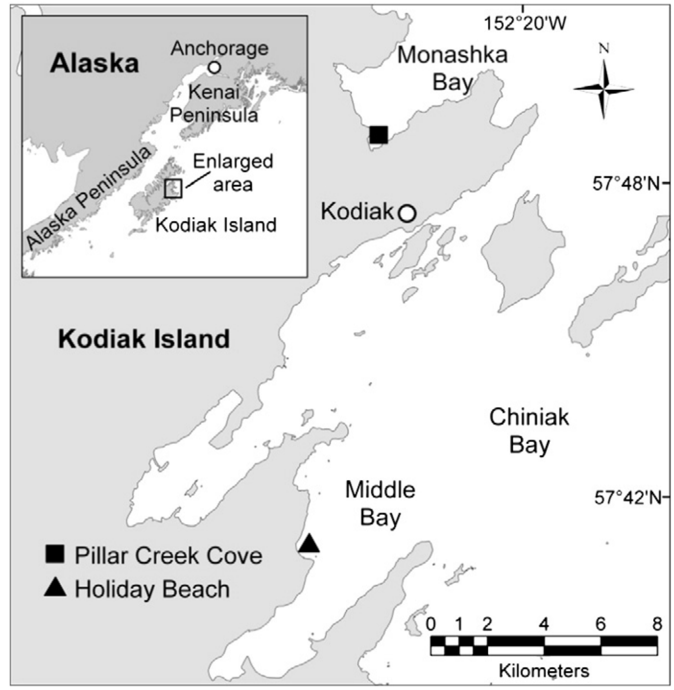

Fig. 1. Location of the Pillar Creek Cove and Holiday Beach study sites in relation to Kodiak Island, and greater Alaska (inset).

2.2. Towed camera sled data

Video surveys were conducted at both sites during mid-July, 2003, 2004, 2006, 2008, and 2009, using a towed camera sled (Spencer et al., 2005; Stoner et al., 2007). Briefly, the sled was towed at an average vessel speed of 60 $cm \cdot s^{-1}$ along 2 or more transects at each site. At Holiday Beach, transects commenced at ~3 m and continued offshore to ~26 m. The 26 m depth marks the beginning of a broad shelf than continues offshore for several kilometers. At Pillar Creek Cove transects commenced at 3–5 m depth and continued to ~37 m depth. Depth continues to increase farther offshore. The operation depth limit for the towed sled is ~40 m. In all, 19 transects were conducted at Holiday; 2 in 2003, 4 in 2004, 2 in 2006, 6 in 2008, and 5 in 2009. Sixteen transects were completed at Pillar; 3 in 2003, 3 in 2004, 2 in 2006, 5 in 2008, and 3 in 2009. The sled was equipped with a tickler chain, which caused flatfish to flush from the bottom. Typical water clarity allowed us to view ~3 m ahead of the sled. GPS positions allowed the distance traversed, and hence the area of the bottom swept by the sled to be calculated. The relative abundance of polychaete worm tubes and density of age 0 yr flatfish was scored during video playback. The vast majority of worm tubes were easily identifiable as *S. sibirica*. *S. sibirica* tubes are distinctive and not easily confused with other polychaetes around Kodiak. The tubes are extremely pliant, 1–1.25 mm in diameter and up to 12 cm long, with approximately 70% of the tube emergent and upright above the sediment surface. Specimens from bottom grabs were definitively identified as *S. sibirica* in 2008 (personal communication; Stephen Jewett, University of Alaska Fairbanks). Polychaete abundance was scored on a 5 point scale (0–4), with 0 representing worm absence, and 4 representing a contiguous 'worm turf' (Stoner et al., 2007, Fig. 2). Worm abundance and counts of age 0 yr flatfish observed between the sled runners (67 cm apart) were recorded during 15 s intervals. Thus, each interval corresponds to distance of approximately 9 m,