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Food Web Fuel Differs Across Habitats and Seasons of a Tidal Freshwater Estuary

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Abstract

Estuarine food webs are fueled by multiple different primary producers. However, identifying the relative importance of each producer to consumers is difficult, particularly for fishes that utilize multiple food sources due to both their mobility and their generally high trophic levels. Previous studies have documented broad spatial differences in the importance of primary producers to fishes within the Upper San Francisco Estuary, California, including separation between pelagic and littoral food webs. In this study, we evaluated the importance of primary producers to adult fishes in three closely spaced subregions that represented disparate habitat types (a tidal wetland channel, a turbid backwater channel, and a deep open-water channel), each a potential outcome of local restoration projects. Using stable isotope analysis coupled with a Bayesian mixing model, we identified significant differences in primary-producer contribution to fishes and invertebrates across habitats and seasons, especially in the relative contribution of submersed aquatic vegetation and phytoplankton. Most fishes utilized multiple primary producers and showed little segregation between pelagic and littoral food webs among habitats. Availability of primary producers differs seasonally and across multiple spatial scales, helping to buffer environmental variability and thus enhancing food web resilience. Ecosystem restoration may improve with emphasis on restoring a wide variety of primary producers to support consumers.

Keywords Stable isotopes · Primary producers · Basal resources · Fishes · San Francisco Estuary

Introduction

Many estuarine food webs appear to be fueled by exported wetland detritus (Teal 1962; Odum 1980; Peterson et al. 1985); however, estuarine consumers also use many other organic-matter sources such as phytoplankton (Deegan and Garritt 1997; Galvan et al. 2008), macroalgae and benthic microalgae (Currin et al. 1995; Kwak and Zedler 1997), submersed aquatic vegetation (SAV; Kitting et al. 1984; Vizzini et al. 2002), and terrestrial vegetation (Chanton and Lewis 2002; Zeug and Winemiller 2008; Tanentzap et al. 2014). Although each source may be an important contributor, the relative importance of each differs substantially across space and time (Peterson et al. 1985; Chanton and Lewis 2002). For example, phytoplankton, benthic microalgae, and marsh vegetation were all important to local consumers in Plum Island Sound, MA, USA, but the relative importance differed depending on location within the estuary (Deegan and Garritt 1997). These spatiotemporal differences stabilize complex food webs (Winemiller 1996; Polis et al. 1997) because diverse sources of productivity maintain consistent support for higher trophic levels (McCann et al. 2005).

Estuaries are particularly complex, with a complicated mix of trophic contributions from marine and freshwater inputs (Fry and Smith 2002; Hoffman et al. 2008; Atwood et al. 2012), with diverse intertidal and subtidal habitats, and with severe human impacts, which include eutrophication, species invasions, and habitat loss (Kennish 2002). Habitat loss can reduce the quantity or availability of different organic matter

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