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Six decades of change in pollution and benthic invertebrate biodiversity in a southern New England estuary

Stephen S. Hale[a,*], Henry W. Buffum[b], Melissa M. Hughes[b]

[a] Atlantic Ecology Division, National Health and Environmental Effects Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, 27 Tarzwell Drive, Narragansett, RI 02882, USA

[b] CSRA, U.S. Environmental Protection Agency, Narragansett, RI, USA 02882

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ABSTRACT

Pollution has led to a decline of benthic invertebrate biodiversity of Narragansett Bay, raising questions about effects on ecosystem functions and services including shellfish production, energy flow to fishes, and biogeochemical cycles. Changes in community composition and taxonomic distinctness (biodiversity) were calculated from the 1950s—when quantitative benthic invertebrate data first became available—to 2015. Change in community composition of the bay was correlated with changes in dissolved inorganic nitrogen, dissolved oxygen, and sediment contaminants. A mid-bay reference site showed moderate changes in community composition but no change in biodiversity. In contrast, a more impacted site in the upper bay showed substantial differences in community composition over time and a decline in taxonomic distinctness. Bay-wide, as inputs of some stressors such as nutrients and sediment contaminants have declined, there are signs of recovery of benthic biodiversity but other stressors such as temperature and watershed development are increasing.

1. Introduction

Biodiversity supports the functioning of ecosystems and the services they provide to people (Worm et al., 2006; Palumbi et al., 2009; Fautin et al., 2010; Solan et al., 2012; Goulletquer et al., 2014; Dornelas et al., in press). Ecosystem functions and services driven by benthic biodiversity include seafood for human consumption, water filtration (water quality), bioturbation and bio-irrigation (supporting nutrient cycling), shoreline protection, habitat for other species, and cultural services such as recreation (Snelgrove et al., 1997; Snelgrove, 1998, 1999; Levin et al., 2001; Weslawski et al., 2004; Goulletquer et al., 2014).

Marine ecosystems around the world have experienced rapid declines in biodiversity as a result of multiple stressors (Snelgrove et al., 2004; Jackson, 2008; Worm et al., 2006; Fautin et al., 2010; McCauley et al., 2015) and quantifying these changes has been recognized as a crucial research need (Fautin et al., 2010; Dornelas et al., in press). Estuarine functions are affected when benthic species losses lead to less food available for fishes, fewer large bioturbators, fewer suspension feeders, loss of reef or mat habitat, or collapse of biological interactions (Goulletquer et al., 2014). Loss of rare species reduces ecosystem functioning, productivity, and the ability to respond to environmental perturbations (Micheli and Halpern, 2005; Mouillat et al., 2013; Obst et al., 2017). Long-term benthic community studies have contributed to an understanding of how the sum of multiple anthropogenic factors over long periods of time has adversely affected biodiversity. Factors implicated include eutrophication and hypoxia (Kemp et al., 2005; Pranovi et al., 2008; Reise et al., 2008; Krann et al., 2011), warming waters (Callaway et al., 2007; Shojaei et al., 2016), commercial fishing (Callaway et al., 2007; Trott, 2016), contaminants and combinations of these (Obst et al., 2017). Benthic communities are good integrators of these cumulative stressors (Obst et al., 2017).

This article describes how species biodiversity and community composition of the soft-bottom benthic invertebrate macrofaunal community of Narragansett Bay has changed over the past six decades and relates changes, where possible, to anthropogenic drivers. Sampling methods that allowed such quantitative comparisons of benthic invertebrates in the bay began in the 1950s. Recently, in an effort to reduce eutrophication and hypoxia, nutrient loads to the bay have been reduced, including a 50% reduction of total nitrogen input from wastewater treatment facilities (WWTF) that occurred 2005–2013 (NBEP, 2017). Additionally, inputs of metals, petroleum hydrocarbons, and synthetic organic contaminants have declined in recent years while other stressors (e.g., water temperature, watershed development) are increasing (NBEP, 2017). Questions arise as to what the effect will be on the estuarine ecosystem. This article explores whether it is possible to detect a benthic response to these changes.

* Corresponding author.
E-mail address: hale.stephen@epa.gov (S.S. Hale).

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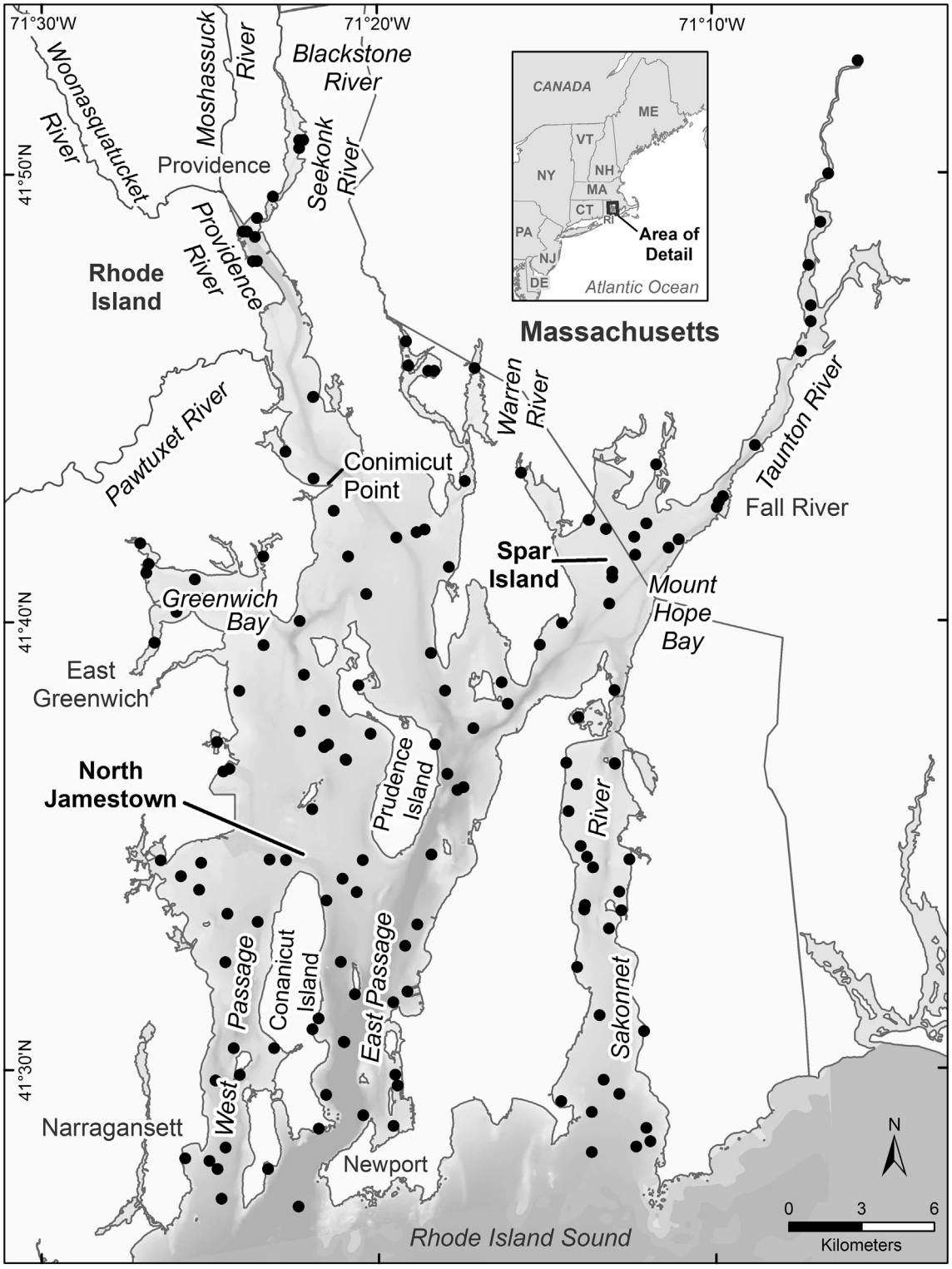

Fig. 1. Map of 166 USEPA stations in Narragansett Bay, Rhode Island and Massachusetts, 1990–2015, showing the location of the North Jamestown and Spar Island sites.

2. Methods

2.1. Study area

Narragansett Bay is a temperate northeastern U.S. estuary in Rhode Island and Massachusetts located at the northern end of the Virginian Biogeographic Province (Fig. 1). Benthic invertebrate biodiversity in the bay stems from a mix of warm temperate species of the Virginian Province and Arctic-boreal species more common in the Acadian Biogeographic Province to the north (Hale, 2010), continental shelf species that extend up into the deep East Passage (Pratt, 1992), and rocky shore habitats at the mouth of the bay that are not common along the southern New England coast (French et al., 1992). The benthic system is closely coupled with the pelagic system and is an important part of the