Ocean & Coastal Management 102 (2014) 375–382

Contents lists available at ScienceDirect

Ocean & Coastal Management

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

Review

Ecological effect of a nonnative seagrass spreading in the Northeast Pacific: A review of *Zostera japonica*

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ARTICLE INFO

Article history:
Received 26 February 2014
Received in revised form
4 October 2014
Accepted 9 October 2014
Available online

Keywords:
Nonnative seagrass
Zostera japonica
Zostera marina
Invasive plant management
Northeast Pacific
Impacts
Ecological effects

ABSTRACT

It is widely accepted that *Zostera japonica*, a seagrass species native to estuarine and coastal habitats of the Western Pacific Ocean, invaded these same habitats in the Eastern Pacific early in the Twentieth Century. Based on the supposition that this species causes harm to native species living in the estuarine and coastal regions of Washington State, in 2012 they started legally allowing local enforcement to remove *Z. japonica*. We executed a literature search to determine if reviewed studies support the contention that *Z. japonica* harms native species and habitats in Washington State and other locations in the Pacific Northwest region of the eastern Pacific Ocean. We found that studies designed to quantitatively assess *Z. japonica*'s impact are limited but provide a summary that suggests *Z. japonica* increases overall diversity of infaunal invertebrates, while decreasing large infaunal species, such as Manilla clam and ghost shrimp, and the native seagrass, *Zostera marina*. Our finding is restricted by a lack of repeated or long-term sampling effort and inadequate treatment of important higher order trophic levels and commercially harvested species in study designs. In this analysis we demonstrate that rigorous scientific investigation is needed before generalized policies, potentially influencing ecosystem productivity, are adopted.

1. Introduction

Nonnative species can impact marine systems by modifying the physical environment and altering community structure (Carlton, 2003). However, despite common descriptive terms for nonnative species that suggest a negative impact, such as “invasive”, “nuisance”, and “noxious” (Colautti and MacIsaac, 2004; Heger et al., 2013), not all nonnative species have adverse consequences (Hershner and Havens, 2008). To evaluate the full suite of biological and physical interactions of a nonnative, we review all observational and experimental studies designed to assess ecological effects of a seagrass species, *Zostera japonica* Aschers & Graebner, outside its native range.

Since the 1500's, trans-Pacific shipping has resulted in the introduction of several marine species to the coasts and estuaries of the Northeast Pacific (NE Pacific) (Wonham and Carlton, 2005). Sometime during this 500-year period, but probably early in the 20th Century, evidence suggests that *Z. japonica*, arrived in two estuaries in Washington State, USA – Samish Bay and Willapa Bay (Harrison and Bigley, 1982). While the introduction of seaweeds and invertebrates via oceanic trade and transport is common, only four seagrass species have been transported outside their native ranges, including *Z. japonica* (these are *Halophila stipulacea*, *Halophila decipiens* and *Zostera tasmanica*; Williams, 2007). The most likely method of introduction, although not tested, was the transfer of propagules (seed and/or vegetative fragments) in the oyster trade with Japan (Harrison and Bigley, 1982). When first found the species was formally identified as *Zostera nana* Roth (Hitchcock et al., 1969), though after further taxonomic analysis the species was re-named *Z. japonica* (Bigley and Barreca, 1982).

The addition of *Z. japonica* to the seagrass flora of the NE Pacific increases the number of seagrass species in this region to six (Wyllie-Echeverria and Ackerman, 2003) and evidence suggests that the presence of *Z. japonica* does not negatively impact native seagrass species in the NE Pacific (Williams, 2007). On the other hand, *Z. japonica* does transform unvegetated mud- and sandflat environments to vegetated habitat with root and rhizome structure

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http://dx.doi.org/10.1016/j.ocecoaman.2014.10.002
0964-5691/

and foliage leaf architecture commonly associated with seagrass presence (reviewed in Hemminga and Duarte, 2000). While this transformation may provide habitat for some species, the elimination of unvegetated biomes can negatively affect other species (e.g., Siebert and Branch, 2007).

Over the last 50 years, since *Z. japonica* was first documented (Hitchcock et al., 1969), the species has spread north to Campbell River, British Columbia, Canada where it was found in 2006 (C. Durance pers comm.) and south to Humboldt Bay, California, USA (Fig. 1; Mach et al., 2010; Shafer et al., 2008). Unfortunately while regional research has focused on *Zostera marina*, little is understood regarding *Z. japonica*'s effects on the biotic and abiotic environment in the NE Pacific (Mach et al., 2010). Until 2010 all eelgrass species, including both *Z. japonica* and *Z. marina*, were protected in Washington State, USA (Pawlak, 1994; Shafer et al., 2014) and thus the political will to fund research regarding impacts of the nonnative species was lacking. However, early in 2011 motivation to control the spread of *Z. japonica* was influenced by stakeholder concerns regarding the economic impacts of this plant to coastal fisheries and aquaculture (Anderson, 2011). Pressure to remove protection of the plant in Willapa Bay, an estuary important for shellfish aquaculture, was followed by Washington State legally allowing local enforcement to remove *Z. japonica* by declaring it a Class C Noxious Weed at the end of 2011, with removal permitted on commercial properties in 2013 (Shafer et al., 2014; Washington State Noxious Weed Control Board, 2012). While removal is being attempted at its southern extent in Northern California with moderate success (Ramey et al., 2011), at its northern extent in British Columbia there are no specific laws regarding protection or removal (Shafer et al., 2014).

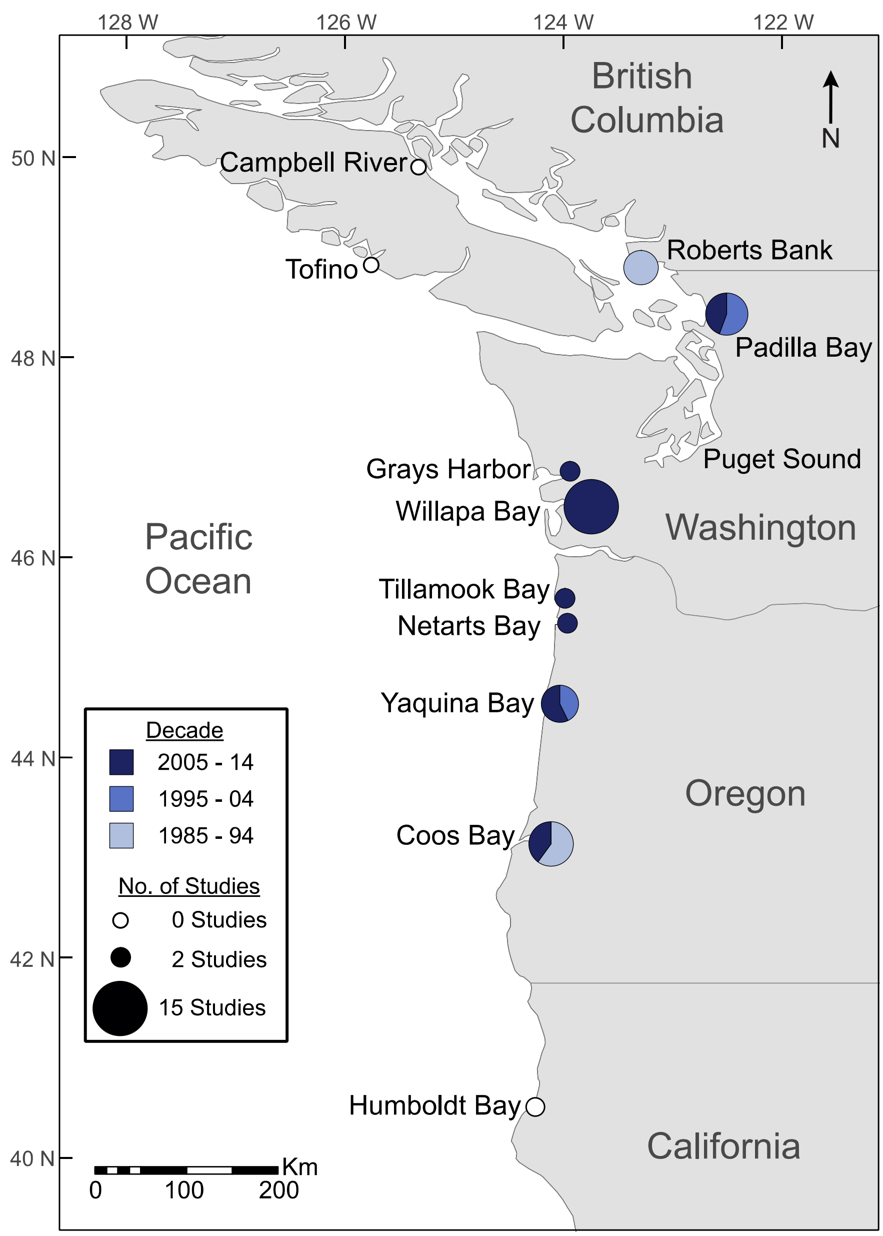

Fig. 1. Map of NE Pacific range of *Zostera japonica* with circles representing the total number of field studies completed testing the effect of *Z. japonica* on the biotic community or abiotic characteristics at each site, and color-tone representing the decade in which those studies occurred. Open circles, at Tofino and Campbell River, are the known northern extent of *Z. japonica*'s range in British Columbia, while Humboldt Bay represents the southern extent in California, where there have been no studies of *Z. japonica*'s ecological effect. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)