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Eelgrass recovery after nutrient enrichment reversal

Jamie M.P. Vaudrey[a,*], James N. Kremer[a], Brett F. Branco[a,1], Frederick T. Short[b]

[a] *Department of Marine Sciences, University of Connecticut, 1080 Shennecossett Road, Groton, CT 06340, USA*
[b] *Department of Natural Resources and the Environment, University of New Hampshire, Durham, NH, USA*

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ABSTRACT

Mumford Cove, a 48 ha Connecticut embayment on Long Island Sound, has a history of excessive nutrient inputs and corresponding eutrophic conditions with concomitant eelgrass (*Zostera marina* L.) loss. From 1945 to 1987, a municipal wastewater treatment facility discharged into the cove. In 1987, when the wastewater outfall was diverted to another location, the cove supported a near monoculture of the green algae *Ulva lactuca* L., covering 74% of the bottom. By 1988, macroalgal areal cover in Mumford Cove had declined to 9%. When we first sampled the cove in 1992, *Z. marina* and *Ruppia maritima* L. were present. By 1999, areal distribution of *Z. marina* and *R. maritima* had expanded to cover a third of the bottom. Periodic summertime surveys from 2002 through 2004 indicated that *Z. marina* was present in approximately half of the cove; *R. maritima* was sparse. Fifteen years after termination of nutrient enrichment, this cove had recovered from 40 years of point source anthropogenic nutrient input, returning from an *Ulva*-dominated to a *Zostera*-dominated state.

1. Introduction

Decline of seagrass populations has been observed in many estuarine embayments, and the declines are often associated with anthropogenic nutrient loading (Short and Burdick, 1996; Duarte, 2002; Hauxwell et al., 2003; Lotze et al., 2006; Orth et al., 2006a; Waycott et al., 2009). Increased availability of nutrients in eutrophic embayments may lead to blooms of macroalgae, phytoplankton, and epiphytes, all of which shade seagrass, reducing the light available for photosynthesis and decreasing seagrass productivity (Harlin and Thorne-Miller, 1981; Short et al., 1995; Hauxwell et al., 2001; Ralph et al., 2007).

Recent management strategies for coastal waters have focused on the use of indicator species to identify systems in need of mitigation (Orth et al., 2002; Neckles et al., 2005; Greening and Janicki, 2006; Steward and Green, 2007; Wazniak et al., 2007). Seagrass ecosystems have been described as “coastal canaries”: loss of seagrass indicates ecosystem degradation and loss of ecosystem services (Orth et al., 2006a). While seagrass populations show a significant decline on a worldwide basis (Waycott et al., 2009), instances of natural recolonization of beds have been documented following physical disturbances (Hastings et al., 1995; Dawes et al., 1997; Olesen et al., 2004; Whitfield et al., 2004; Hammerstrom et al., 2007; Di Carlo and Kenworthy, 2008; Martin et al., 2008; Boese et al., 2009); construction (Park et al., 2009); storm events (Preen et al., 1995; Campbell and McKenzie, 2004; Frederiksen et al., 2004; Kendall et al., 2004; Fernandez et al., 2006; Ridler et al., 2006); the 1930s wasting disease outbreak (Rasmussen, 1977; Frederiksen et al., 2004); anoxic events (Plus et al., 2003; Greve et al., 2005); and accumulation of organic matter (Morris and Virnstein, 2004). A number of studies document seagrass recovery following reduction of anthropogenic nutrient inputs (Table 1). Two of these cases involve recolonization by *Zostera marina* L. (eelgrass). In the first case, a large expansion of eelgrass from 1986 to 2001 corresponded with nutrient reduction and improving water quality in a number of bays on the Delmarva Peninsula, MD, U.S.A. (Wazniak et al., 2007; Orth et al., 2010). However, a subsequent decline occurred after 2001, associated with increasing nutrient inputs and a degradation of water quality (Orth et al., 2010). In the second case, Boston Harbor, nutrient inputs from wastewater treatment facilities were reduced by 90% between 1997 and 2000 (Taylor, 2010). In 2008, a *Z. marina* patch was found at 1 of the 60 sampling stations, though areal extent and long-term stability of the bed were not quantified (Maciolek et al., 2009).

Documenting cases of natural seagrass recovery provides information to the management community on potential recovery time and expansion rates for seagrass recolonization of disturbed areas. An understanding of the time frame for this process allows for the development of realistic goals for seagrass recolonization following

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* Corresponding author. Tel.: +1 860 405 9149; fax: +1 860 405 9153.
E-mail address: jamie.vaudrey@uconn.edu (J.M.P. Vaudrey).
[1] Present address: Department of Geology, Brooklyn College, Brooklyn, NY, USA.

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Table 1
Documented cases of natural seagrass recovery following nutrient load reductions.

Species	Location	Remediation	Area studied (km^2)	Pre-existing bed size (ha)	Area recovered (ha)	Time period of recovery	Selected references
Halodule wrightii	Tampa Bay, Florida, USA	N reduction in domestic wastewater discharges (57% reduction, 1976–1992)	959	8800	2171	1982–2004	Johansson and Lewis (1992) Greening and Janicki (2006)
Mixed beds, dominant: *Halophila australis*	Gulf St., Vincent, Southern Australia	N reduction, sewer sludge outfall decommissioned (October, 1993)	0.02[a]	0	0.56[a]	1993–2001	Bryars and Neverauskas (2004)
Posidonia australis, *Posidonia sinuosa*	Oyster Harbor, Western Australia	N and suspended solids reduction, decrease in agricultural run-off	16	[b]	[b]	1988–1996	Cambridge et al. (2002)
Posidonia oceanic	Marseilles, France	N reduction, WWTF opened	0.005[c]	C	0.18[c]	1987–1999	Pergent-Martini et al. (2002)
Thalassia testudinum	Sarasota Bay, Florida, USA	N reduction in domestic wastewater discharges (46% reduction, 1988–2002)	135	3416	214	1988–2002	Tomasko et al. (2005)
Zostera noltii	Mondego Estuary, Portugal	N reduction , altered flow regime (40–50% N reduction, 1998)	3.4	0.02	3.98	1997–2004	Cardoso et al. (2010)
Zostera marina	Delmarva Peninsula, Maryland, USA	N and P reduction, better management of anthropogenic sources					
	Assawoman Bay		21[d]	0	265	1991–1999[e]	Orth et al. (2006b)
	Chincoteague Bay		377[d]	2100	4695	1986–2001[e]	Orth et al. (2006b)
	Isle of Wight Bay		21[d]	0	135	1992–2003[e]	Orth et al. (2006b)
	Newport Bay		16[d]	0	46	1990–2002[e]	Wazniak et al. (2004)
	St. Martin River		8.4[d]	0	0.8	1999–2002[e]	Wazniak et al. (2004)
	Sinepuxent Bay		24[d]	12	743	1986–2002[e]	Orth et al. (2006b)
Z. marina	Boston Harbor, Massachusetts, USA	N reduction, relocated 2 WWTF outfalls (90% reduction, primarily 1997–2000)	122	0	[f]	2000–2008	Maciolek et al. (2009), Taylor (2010)
Z. marina	Mumford Cove, Connecticut, USA	N reduction, relocated WWTF outfall (>66% reduction, October 1987)	0.5	0	25	1987–2002	This study

[a] Sampled a 2 ha area near the decommissioned outfall. An area of 365 ha around the outfall had completely lost seagrass.

[b] *Posidonia australis* radial expansion rate from 20 naturally occurring patches averaged 20 cm y^{-1}, 1994–2000, no area provided.

[c] Determined by tracking the reclamation of a sand patch (0.5 ha) in the seagrass bed. Deep edge of bed also expanded, no area provided.

[d] Data are from the Coastal Bays Program, http://www.mdcoastalbays.org/bays.

[e] Year of first appearance or monitoring—year of maximum abundance. In subsequent years seagrass has declined (Orth et al., 2010).

[f] Present at one station (of 60) in 2008, area not quantified.