SEAGRASSES

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1. OVERVIEW

Seagrasses are aquatic vascular flowering plants that help stabilize sediments and provide vital habitat and nursery grounds for fish and shellfish. Because of its ecological value, seagrass is an important indicator of ecosystem condition in Narragansett Bay. Prior to the 1940s, the total extent of seagrass acreage in the estuarine waters of the Bay was vast—encompassing almost all sections of the Bay including the Providence River estuary and Mount Hope Bay. Seagrasses then declined markedly, and now they are found only in the lower Bay.

The decline was caused by stressors such as nutrient enrichment (which encourages algae and epiphyte growth, thus shading the grass) and physical disturbance (such as dredging, removal, and storms), as well as by a disease outbreak in the 1930s that caused extensive losses along the Atlantic Coast. Today, nutrient enrichment continues to be an important stressor, and climate change is increasingly affecting seagrasses through warming waters and rising sea level.

This chapter reports on the status of seagrass in Narragansett Bay based on three mapping efforts conducted in 2006, 2009, and 2012. (Mapping data were also collected in 2016, but the results are not yet available for reporting.) In 2012, 513 acres of seagrass were mapped in Narragansett Bay; in portions of the Bay that were mapped in both 2006 and 2012, there was a 29 percent increase in seagrass acreage between those surveys. In the Southwest Coastal Ponds, 603 acres were mapped in 2012, a decrease of 80 acres from 2009. The mapping effort in 2012 also documented 201 acres of seagrass in Little Narragansett Bay, which was not included in the 2006 study area.

2. INTRODUCTION

Two types of seagrasses are found in Narragansett Bay: eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*). Eelgrass is a predominantly estuarine species, while widgeon grass thrives in lower salinity waters (Kantrud 1994). Eelgrass is taller than widgeon grass, and the two species have been observed intermixing within seagrass beds in Narragansett Bay (Peg Pelletier, USEPA-Atlantic Ecology Division, Narragansett, personal communication). To date, most seagrass research in Narragansett Bay has focused on eelgrass, and additional research on widgeon grass would be very useful for a more comprehensive understanding of seagrass dynamics.

Because seagrasses require abundant light, they are restricted to shallow areas with clear water. The slope of the substrate and the amount of light that can penetrate the water determine the greatest distance that seagrass can grow from shore (Dennison and Alberte 1985, Mann 2000). Seagrasses in the temperate zones flower between 10-20°C (50-70°F). They live in areas with low nutrient input, as high nutrient levels tend to favor algae, phytoplankton, and epiphytic growth that shade seagrasses and reduce their growth (Mann 2000). Seagrasses are perennial plants, but in the shallowest areas (less than 1 meter [3.3 feet] depth), they may be considered functional annuals because the plants are often killed by ice scouring, freezing, and other seasonal stresses (Costa 1988).

Seagrass beds are highly productive and help to create complex habitats for a diversity of other species above and below the surface sediment, maintaining the physical, chemical, and biological integrity of the ecosystem (e.g., Thayer et al. 1975, Collette and Klein-MacPhee 2002, Liu and Nepf

2016). They provide nursery grounds, refuge, and feeding grounds for many commercially important and charismatic organisms, such as bay scallops, flounder, striped bass, tautog, and seahorses (e.g., Heck et al. 1989). Additionally, seagrasses bind and stabilize sediment by slowing water currents and causing sediment to drop out of the water column (Liu and Nepf 2016). This provides food for animals that feed on the bottom and creates clearer water, which increases the amount of light reaching the seagrass blades (Orth 1977).

The productivity of seagrass beds makes them potentially valuable candidates for long-term carbon storage to mitigate the impacts of climate change (known as blue carbon). Seagrasses accumulate carbon through both primary production and sedimentation, and the amount of carbon sequestered varies with the type of grass and the size of the bed (Lavery et al. 2013, Greiner et al. 2013). Data on organic carbon content of living seagrasses and sediment in seagrass meadows shows a significant amount of storage capability—roughly 4.2-8.4 Pg carbon (Fourqurean et al. 2012). The amount of organic carbon stored per area of seagrass is similar to that of forests worldwide (Fourqurean et al. 2012). Protection and conservation of seagrass beds are valuable actions to enhance global and regional resilience to climate change.

The ecological and societal value of seagrasses makes it critical to adequately monitor trends in the extent and condition of seagrass beds. Seagrasses are considered "coastal canaries" because the loss of seagrass often indicates ecosystem degradation and loss of ecosystem services, which can result in habitat regime shifts (Orth et al. 2006, Costello and Kenworthy 2011). This report discusses the extent of seagrasses in 2012 in the context of other recent and historical data, and it explores how present and future stressors such as nutrient loading, warmer temperatures, and sea level rise may affect seagrasses.

3. METHODS

Several surveys of seagrass have been conducted in Narragansett Bay and nearby waterbodies in the past twenty years (Table 1). In 1996 and 1999, the Narragansett Bay Estuary Program and partners commissioned aerial photography to map seagrass habitat (Huber 1999 and 2003). The 1996 survey documented approximately 100 acres of seagrass in Narragansett Bay. The 1999 survey focused on Little Narragansett Bay and the Southwest Coastal Ponds, where it found approximately 61 acres and 473 acres of seagrass, respectively. Starting in 2006, the Rhode Island Eelgrass Task Force (Task Force) continued and refined these efforts by developing a set of mapping and monitoring protocols (Raposa and Bradley 2009). The Task Force is composed of researchers from the University of Rhode Island, state agencies, and non-profit organizations. Seagrass surveys using the Task Force protocols were conducted in 2006 (Narragansett Bay), 2009 (Southwest Coastal Ponds), and 2012 (Narragensett Bay, Southwest Coastal Ponds, Little Narragansett Bay).

Technological and methodological differences between the 1990s surveys and the 2000s surveys make statistical comparisons, resolution, and analysis of change between them problematic (Bradley et al 2007). For that reason, this report focuses on data from the 2006, 2009, and 2012 surveys (Bradley et al. 2007, 2013).

Table 1. Inventory of seagrass surveys using aerial photography in Narragansett Bay, Little Narragansett Bay, and the Southwest Coastal Ponds since 1996.

Year Photographs Taken	Study Areas	Orthophotograph Resolution	Citation
1996	Narragansett Bay	1:12,000	Huber 1999
1999	Southwest Coastal Ponds and Little Narragansett Bay	1:12,000	Huber 2003
2006	Narragansett Bay	1:5,000	Bradley et al. 2007
2009	Southwest Coastal Ponds	1:5,000	Bradley et al. 2013
2012	Narragansett Bay, Southwest Coastal Ponds, and Little Narragansett Bay	1:5,000	Bradley et al. 2013

The Task Force developed a three-tiered system (Raposa and Bradley 2009) for monitoring and mapping seagrasses, based on the work of Neckles et al. (2012). In Tier 1, mapping is performed based on aerial photography with seagrass signatures digitized by a GIS technician; fieldwork is then conducted to augment and ground-truth the mapped seagrass beds. The Task Force recommended conducting Tier 1 mapping and ground-truthing every 3 to 5 years. The 2006, 2009, and 2012 mapping efforts were Tier 1 mapping assessments conducted in Narragansett Bay, Little Narragansett Bay, and the Southwest Coastal Ponds. The Tier 1 methodology and results are summarized in Bradley et al. (2007, 2013). Data from the other two tiers in the three-tiered system are not included in this report but are important to summarize as background for the Data Gaps and Research Needs section. In Tier 2, a subset of seagrass beds is monitored annually for percent cover and other metrics of eelgrass condition. Currently, Tier 2 monitoring is conducted only at one seagrass bed in Narragansett Bay, at the southern end of Prudence Island. In Tier 3, biomass and other metrics are monitored repeatedly over multiple time scales within individual sites, following the SeagrasssNet protocol (Short et al. 2002a). Although Tier 3 monitoring occurred at two sites (Fort Getty in Jamestown and T-Wharf on Prudence Island) from 2005 to 2013, it is currently suspended due to lack of funding.

We analyzed eelgrass status in the 2006 and 2012 surveys, and assessed persistence of eelgrass beds between the two surveys. Areas of seagrass present in both surveys were considered persistent, while other areas were classified as either gains or losses of seagrass acreage. We also conducted a persistence analysis for Southwest Coastal Ponds using data from the 2009 and 2012 surveys. We were unable to analyze persistence in Little Narragansett Bay because only one year of data was available. Because no formal error analysis has been conducted yet for the survey datasets, we rounded all acreages to whole numbers to allow for error within the analysis. Because this report focuses on only two years of data, we discuss differences in seagrass coverage as changes, not as trends. However, interpretation of aerial photographs taken by the Task Force in 2016 is underway, and in future updates to this report we intend to include a trend analysis.

To examine historical changes, we conducted a presence-and-absence analysis of seagrass based on a comprehensive review of historical documents and oral history ranging from 1848 to 1994 (Kopp et al. 1992, Doherty 1995) and a comparison of those findings with more recent Task Force assessments (Bradley et al. 2007, 2013). The U.S. Coast and Geodetic Survey performed extensive surveys from 1832 to 1948 that noted seagrass locations. Other records relating to seagrass distributions were found in archives, herbariums, and reports. Oral interviews were also conducted to obtain information on past or present eelgrass locations. The Narragansett Bay Estuary Program performed a geospatial analysis of the historical data and developed a presence/absence analysis for sections of the Bay (Doherty 1995). Importantly, the historical analysis did not attempt to quantify seagrass acreage, only presence or absence.

4. STATUS AND TRENDS

A. Narragansett Bay

In 2012, 513 acres of seagrass were mapped in Narragansett Bay (Table 2). However, 29 acres were widgeon grass in Greenwich Bay and 24 acres were in the Narrow River, a newly measured area for 2012. Removing Greenwich Bay and the Narrow River from the calculations, Narragansett Bay gained 103 acres of seagrass between 2006 and 2012, a 29 percent increase. This recent increase in area occurred primarily in the Sakonnet River (48 acre gain), the East Passage (48 acre gain), and the West Passage (37 acre gain) (Table 2).

The seagrass beds in Narragansett Bay showed strong persistence between 2006 and 2012 (Table 2). Almost 85 percent of the 2006 acreage was also mapped in 2012, indicating that the center of the beds was seemingly stable in the six years between surveys.

Table 2. Changes in seagrass acreage in Narragansett Bay between 2006 and 2012. Acreage values were rounded to the nearest whole number. Data are reported for sections (**bold**) and subsections (plain) of Narragansett Bay. Persistence is the number of acres that were consistent between the two years of record. N/A means not applicable because 2006 acreage was zero or unknown. N/D means no data were collected.

Narragansett Bay Sections	Total Acreage		Persistence
	2006	2012	(acres)
Providence River Estuary	**0**	**0**	**N/A**
Warren, Palmer, & Barrington Rivers	**0**	**0**	**N/A**
Taunton River	**0**	**0**	**N/A**
Upper Narragansett Bay	**0**	**0**	**N/A**
Mount Hope Bay	**0**	**0**	**N/A**
Greenwich Bay[1]	**0**	**29**	**N/A**
Apponaug Cove	0	0	N/A
East Greenwich Bay	0	3	N/A
West Greenwich Bay	0	25	N/A
West Passage	**55**	**91**	**44**
Upper West Passage	3	2	1
Wickford Harbor	5	7	5
Middle West Passage	15	29	12
Lower West Passage	32	53	25
East Passage	**210**	**258**	**183**
Middle East Passage	89	112	77

Newport Harbor	4	6	3
Lower East Passage	118	140	103
Sakonnet River	**31**	**52**	**26**
Lower Sakonnet River	31	52	26
Narrow River	**N/D**	**24**	**N/A**
Mouth of Narragansett Bay	**61**	**59**	**48**
Gooseberry Bay	35	21	28
Mouth of Narragansett Bay	26	38	20
TOTAL	**357**	**513**	**301**

[1]In 2012, widgeon grass was mapped in Greenwich Bay; neither eelgrass not widgeon grass was evident during the 2006 mapping event.
[2]The Narrow River was not included in the 2006 mapping effort.

The historical analysis of seagrass coverage in Narragansett Bay showed that seagrasses were widespread throughout the Bay until the middle of the twentieth century and then gradually disappeared from the upper Bay (Table 3). Seagrass was present in 8–9 sections of the Bay in the twentieth-century surveys. In recent surveys, it was present in only 4 (2006) and 6 (2012) sections—all in the lower Bay.

Table 3: Comparison of historical presence of seagrass (1840-1994) to recent presence (2006 and 2012). Green cells indicate presence of seagrass documented in Kopp et al. (1992), Doherty (1995), Bradley et al. (2007), or Bradley et al. (2013). Light pink segments preceding red segments indicate likely presence of seagrass based on Kopp et al. (1992) and Doherty (1995). "Unknown" indicates no evidence of seagrass presence; this does not imply absence, just no evidence of presence. For the 2006 and 2012 data, a blank cell indicates no seagrass found. Thick vertical line indicates the separation between historical data and the recent data.

Narragansett Bay Sections	1840-1899	1900-1939	1940-1979	1980-1994	2006	2012
Providence River Estuary						
Upper Providence River			*Unknown*	*Unknown*		
Bullocks Cove				*Unknown*		
Middle Providence River						
Lower Providence River						
Warren, Palmer, & Barrington Rivers						
Warren River			*Unknown*	*Unknown*		
Barrington River				*Unknown*		
Palmer River						
Taunton River	*Unknown*	*Unknown*	*Unknown*	*Unknown*		
Upper Narragansett Bay						
Upper Bay						
Mount Hope Bay						
Lower Cole River			*Unknown*	*Unknown*		
Lee River			*Unknown*	*Unknown*		
Upper Cole River			*Unknown*	*Unknown*		

Narragansett Bay Sections	1840-1899	1900-1939	1940-1979	1980-1994	2006	2012
Mount Hope Bay				*Unknown*		
Kickemuit River				*Unknown*		
Greenwich Bay						
Greenwich Cove			*Unknown*	*Unknown*		
East Greenwich Bay						
Buttonwoods Cove			*Unknown*	*Unknown*		
Warwick Cove			*Unknown*	*Unknown*		
West Greenwich Bay						
Apponaug Cove			*Unknown*	*Unknown*		
West Passage						
Potowomut River						
Wickford Harbor						
Middle West Passage						
Bissel Cove				*Unknown*		
Dutch Harbor			*Unknown*	*Unknown*		
Quonset Harbor						
Upper West Passage						
Lower West Passage						
East Passage						
Upper East Passage						
Lower East Passage						
Newport Harbor						
Middle East Passage						
Potter's Cove				*Unknown*		
Bristol Harbor						
Sakonnet River						
Nannakuaket Pond				*Unknown*		
The Cove						
Lower Sakonnet River	*Unknown*					
Upper Sakonnet River	*Unknown*					
Narrow River	*Unknown*	*Unknown*	*Unknown*	*Unknown*	*Unknown*	
Mouth of Narragansett Bay						
Gooseberry Bay	*Unknown*					
Mouth of Narragansett Bay						
Sections of Narragansett Bay with Known Presence of Seagrass	9	9	9	8	4	6

B. Southwest Coastal Ponds

In 2012, a total of 523 acres of seagrass were mapped in the Southwest Coastal Ponds by the Rhode Island Eelgrass Task Force (Table 4). Between 2009 and 2012, the Southwest Coastal Ponds lost 80 acres of seagrass, or approximately 15 percent, and the loss appeared to be concentrated in Green Hill, Ninigret, and Quonochontaug Ponds.

Table 4. Seagrass acreage for the Southwest Coastal Ponds in 2009 and 2012. **Bold** indicates total acreage for all Ponds. Persistence indicates the area of seagrass beds that were present in both surveys. Acreage values were rounded to nearest whole number.

	Seagrass Acreage		Persistence (acres)
	2009	2012	
Southwest Coastal Ponds	**603**	**523**	**344**
Green Hill Pond	138	91	68
Ninigret Pond	203	193	129
Point Judith Pond	94	101	59
Potter Pond	75	67	40
Quonochontaug Pond	93	71	47

C. Little Narragansett Bay

In 2012, 201 acres of seagrass were mapped in Little Narragansett Bay by the Rhode Island Eelgrass Task Force.

5. DISCUSSION

Seagrass was more prevalent throughout Narragansett Bay before the 1940s, particularly in the northern sections of the Bay including Fox Point in the Upper Providence River, Mount Hope Bay, Hundred Acre Cove in the Barrington River, Potter Cove on Prudence Island, Greenwich Bay, and other locations in the northern reaches of the Bay (Chintala et al. 2015, Pesch et al. 2012, Nixon et al. 2008, Barrett et al. 2006, Doherty 1995, Kopp et al. 1992; Table 3). From 1840 to 1940, seagrass was noted in many sections of the Bay currently devoid of seagrass. From 1940 to 1994, seagrass coverage declined throughout the Bay, except for a few small beds in the northern sections and larger beds in the southern sections (Doherty 1995, Kopp et al. 1992).

Cicchetti (in prep.) concluded that almost 90 percent of seagrass acreage in the Providence River estuary and Upper Narragansett Bay has been lost since the 1900s. The losses occurred in pulses associated with multiple factors, such as nutrient enrichment and physical removal from dredging and filling activities. From the 1930s through the 1960s, dramatic declines in seagrass acreage were reported (Kopp et al. 1992, Doherty 1995, Short et al. 1996). These declines were most likely due to increased nutrient input from a burgeoning population, punctuated by severe losses from the wasting disease in the 1930s and two major hurricanes (1938, and Carol, 1954) (Costa 1988, Kopp et al. 1992, Short et al. 1993, Doherty 1995).

From 2006 to 2012, Narragansett Bay showed substantial gains in seagrass acreage, although the gains are not enough to replace the acreage lost since the 1940s (Table 3). Although a direct comparison with data from the 1996 survey (Huber 1999) is not possible because of methodological differences, there does seem to have been a substantial increase between 1996 and 2012. The 1996 survey found approximately 100 acres, compared to 513 acres in the 2012 survey. The difference is so great that it probably outweighs any methodological differences between the two datasets, leading researchers to believe that seagrass extent in Narragansett Bay did, in fact, increase over that time period, even if the magnitude of the increase is unclear (M. Bradley, University of Rhode Island, personal communication). This view is supported by the observation that some seagrass study sites (e.g., Fort Getty and T-Wharf) did appear to have increases in seagrass extent during the same time period (Bradley et al. 2007).

The sudden appearance of widgeon grass in Greenwich Bay is also noteworthy. According to the information available, either seagrass was not present in Greenwich Bay in 1996 or early 2006, the bed was too small to be mapped, or it was not immediately visible on the photography. However, the historical analysis showed presence of seagrass in East and West Greenwich Bay up through 1994 (Table 3). Widgeon grass can tolerate fresher and warmer water than eelgrass (Kantrud 1994) and is prevalent in the Southwest Coastal Ponds and Briggs Marsh (located on the southeast side of the Sakonnet River, just outside the study area). It is unknown why seagrass apparently disappeared from Greenwich Bay for nearly a decade.

While many factors affect seagrasses—such as disease, storms, ice scouring, and dredging—three key stressors are especially important with respect to present-day and future status and trends: nutrient loading, temperature, and sea level rise.

Nutrient Loading

In the past, degradation of water quality appears to have been the main cause of seagrass loss (Costa 1988, Valiela et al. 1992, Hauxwell et al. 2003). Increased plankton productivity, epiphyte growth, and turbidity (due to nutrient enrichment) are often invoked as the reasons for light limitation leading to seagrass decline (Kemp et al. 1983, Duarte 1995, Taylor et al. 1999, Pryor et al. 2007, Chintala et al. 2015). The recent gains in seagrass acreage in Narragansett Bay likely stemmed from improved water quality. A reduction in nutrient loading from local wastewater treatment facilities (see “Nutrient Loading” chapter) likely reduced epiphyte coverage on seagrass leaves, phytoplankton blooms, and macroalgae growth, improving water clarity (see “Water Clarity” chapter). An improvement of water clarity allows light to penetrate to greater depths, allowing seagrass beds to expand.

Temperature

Warming waters can affect the spread of seagrass diseases, stress the plants, and influence how they reproduce. As waters warm, diseases such as wasting disease may spread more quickly. A combination of other climate impacts and anthropogenic factors can also exacerbate wasting disease outbreaks (Short et al. 1993, Doherty 1995). To date, wasting disease has not been observed even though temperature is warming in Narragansett Bay (Fulweiler et al. 2015).

In the temperate zone, seagrasses can reproduce in two ways: by extending new shoots and rhizomes, or through seed propagation. Warming waters may promote seed propagation instead of rhizome and shoot growth, particularly at high temperatures near or above 25-30°C (77-86°F) (Phillips et al. 1983, Short and Neckles 1999). While seed germination can promote expansion of seagrass beds into new areas, if conditions are such that seed germination is restricted or a seed bank cannot be established (Harwell and Orth 2002), then seagrass may suffer and decline. Surface waters in the main channel of Narragansett Bay (Fox Island, West Passage) do not show sustained temperatures above 25-30°C (77-86°F) during the summer months (June, July, August, September;

Figure 1). However, temperatures have risen approximately 2°C (3.6°F) over the last 50 years (see "Temperature" chapter).

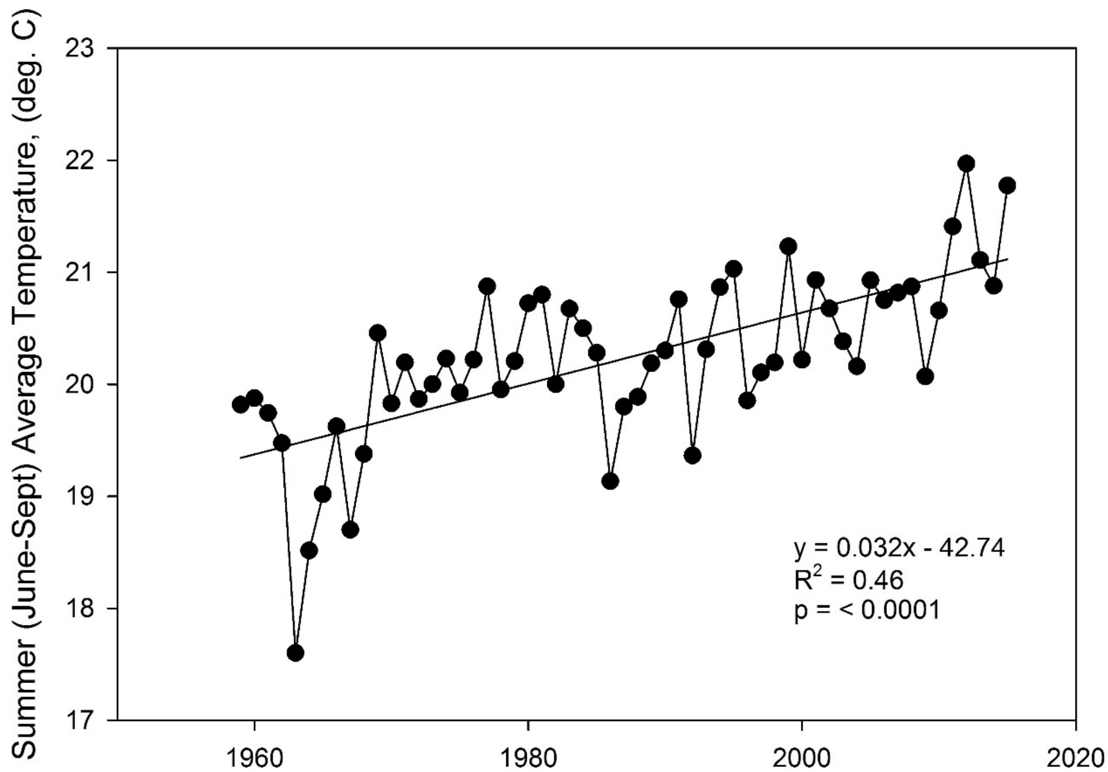

Figure 1. Summer (June, July, August, September) average temperature from 1959-2015. Data are from the GSO Fish Trawl Survey (http://www.gso.uri.edu/fishtrawl/) at Fox Island, located in the West Passage of Narragansett Bay.

Sea Level Rise

Sea level rise is expected to change the tidal regime and water depth of Narragansett Bay, affecting the distribution of seagrasses (Short and Neckles 1999, Saunders et al. 2013, USEPA 2016). Increased tidal range would increase water depth, depending on local geomorphology. A potential outcome would be reducing the intertidal exposure at low tide, allowing the grasses to thrive, while another outcome would be reducing light availability on the seaward side of the bed through increased depth (Short and Neckles 1999). Additionally, increased sea level rise may lead to more saline waters, particularly in tidally restricted areas with low groundwater or freshwater input. This may shift seagrass populations to eelgrass-dominated beds in some places where widgeon grass flourished previously.

With increased water depth, light penetration may become limiting in places where seagrass currently grows, leading to decreases in seagrass productivity and changes in seagrass condition. Short and Neckles (1999) estimated that a 50-centimeter (19.7-inch) increase in water depth would reduce seagrass growth by 30-40 percent, and in Moreton Bay, Australia, Saunders et al. (2013) predicted seagrass habitat would decline 17 percent by 2100 if sea level rises 1.1 meters (3.6 feet) (see projections in "Sea Level" chapter). In a process potentially offsetting some losses caused by deeper water, seagrass beds can expand landward with sea level rise, if they are not blocked by coastal development or hardening. Saunders et al. (2013) predicted that if impervious surfaces could be removed from newly inundated regions, loss of seagrass in Moreton Bay could be reduced to 5 percent.

These stressors and others will affect not only the extent but the condition of seagrass beds. If the extent shrinks or the condition deteriorates, seagrass habitats and the larger ecosystem they support will also deteriorate. The capacity for seagrass beds to store blue carbon would also decrease, and stored organic carbon could even be released as sediments de-stabilize.

Southwest Coastal Ponds

The Southwest Coastal Ponds experienced a loss of about 80 acres from 2009 to 2012 (603 acres to 524 acres). The Rhode Island Eelgrass Task Force also found a change in seagrass composition with widgeon grass increasing in Ninigret Pond (M. Bradley, University of Rhode Island, personal communication). Given that widgeon grass tolerates fresher and warmer waters than eelgrass, this finding suggests that the physical condition of Ninigret Pond may be changing. More monitoring is needed to understand this change.

Although data from the 1999 seagrass mapping effort (Huber 2003) are not directly comparable to the 2012 Task Force data, the 1999 survey found 473 total acres of seagrass in the Southwest Coastal Ponds (Huber 2003). The majority of the acreage was in Ninigret Pond, much like today. Point Judith Pond had the least seagrass acreage in 1999, whereas Potter Pond did in 2012. The differences suggest fluctuations in seagrass coverage in the ponds, although more monitoring is necessary to understand the dynamics.

Previous studies showed that suburbanization in this region caused a past decline of seagrasses (Short et al. 1996). The Southwest Coastal Ponds experienced increased nitrogen loading from septic systems, which contributed to a 41 percent decline in eelgrass over a 32-year period (Short et al. 1996). We have no direct evidence to link the reduction of seagrasses in the Ponds from 2009 to 2012 to nutrient enrichment. Nutrient budgets and further study would be needed to understand if nutrient enrichment is still a major factor affecting seagrass in the Ponds. In addition, the average summer water temperatures may be higher because of reduced flushing and shallow depths. If these trends continue, seagrasses may become stressed.

Little Narragansett Bay

In 2012, the Rhode Island Eelgrass Task Force mapped 201 acres of seagrass in Little Narragansett Bay. The previous estimate was 61 acres in 1999 (Huber 2003), although differences in methods make the data not directly comparable. Additionally, the United States Fish and Wildlife Service (USFWS) analyzed 1:20,000 true-color aerial photographs of Little Narragansett Bay and reported 343 acres of eelgrass in 2009 and 327 acres in 2012 (Tiner et al. 2010, 2013). The USFWS 2012 estimate was 126 acres higher than the Task Force's estimate (Bradley et al. 2013). The difference in acreage may be due to differences in methodology and study area boundaries (Tiner et al. 2013).

6. DATA GAPS AND RESEARCH NEEDS

The Rhode Island Eelgrass Task Force's recommendations for a three-tiered approach to seagrass mapping and monitoring (Raposa and Bradley 2009; see also Methods section above) need to be implemented in order to conduct seagrass analysis more systematically. Presently Tier 1, 2, and 3 efforts in Narragansett Bay are conducted opportunistically when funding is available, resulting in differences in sampling intervals and potentially large temporal gaps in the data sets. In Chesapeake Bay, Tier 1 mapping efforts have been conducted annually since the 1980s (Orth et al. 2010a, Orth et al. 2010b). The Task Force recommended conducting Tier 1 mapping at 3-5 year intervals. In Narragansett Bay, mapping has occurred in 2006, 2012, and 2016, representing a 4-6 year sampling interval. Tier 2 monitoring, which would include assessing seagrass cover annually at a subset of sites throughout the Bay, is currently only being done at one site on Prudence Island; additional sites need to be added. Tier 3 monitoring—implementation of the SeagrassNet protocol—was conducted previously at Fort Getty and Prudence Island, but it has been suspended due to lack of funding. Tier 2 and 3 monitoring would generate data on biomass, percent cover, and other metrics that provide essential information on the status of individual sites. If the seagrass beds of Narragansett Bay are changing because of factors such as climate change or nutrient enrichment, knowledge of how these metrics are changing would aid future management decisions.

With the establishment of the Task Force protocols and methodology (Raposa and Bradley 2009), an error analysis needs to be conducted for seagrass mapping data in Narragansett Bay. This analysis would enable surveys from 2006 onward to be compared statistically. In turn, we would be able to develop enhanced data products that show with greater certainty how seagrass extent is changing over time throughout all the study areas.

In addition to implementing the three-tiered system, we need to better understand the life history traits of eelgrass and widgeon grass in Narragansett Bay. Recent research by the United States Environmental Protection Agency has studied optimal growing conditions (P. Pelletier, USEPA, personal communication), but we lack knowledge of how these conditions will affect reproduction, and how reproductive strategies affect the extent and conditions of the seagrass beds. Of particular interest is widgeon grass, as it is far less studied than eelgrass. Extensive mesocosm experiments on the response of eelgrass to nutrients, temperature, and other interactive factors have been conducted in Rhode Island (e.g., Bintz and Nixon 2003, Taylor et al. 1999). These types of studies should be pursued for widgeon grass, as well as for seagrass communities composed of both eelgrass and widgeon grass.

Climate change is an issue facing our seagrass beds. Warming temperatures, changes in precipitation patterns, ocean acidification, and sea level rise can all affect how the beds survive from year to year. Research, both in controlled mesocosms and field experiments, is needed to fully understand how the beds will respond, such as whether the grasses will switch reproduction types and whether they will become stressed enough to be vulnerable to storms and other destructive forces.

As demonstrated in the Chesapeake Bay (Orth et al. 2010a and b), a program of frequent seagrass mapping and condition assessment, coupled with monitoring of water quality, temperature, water clarity, and other factors that affect seagrass growth, would provide important information for seagrass restoration and conservation efforts in Narragansett Bay. Further, trends in seagrass extent can serve as a valuable indicator of how other biotic components of the Bay are responding to nutrient reduction efforts.

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