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Widespread recovery of seagrass coverage in Southwest Florida (USA): Temporal and spatial trends and management actions responsible for success

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ABSTRACT

In Southwest Florida, a variety of human impacts had caused widespread losses of seagrass coverage from historical conditions. St. Joseph Sound and Clearwater Harbor lost approximately 24 and 51%, respectively, of their seagrass coverage between 1950 and 1999, while Tampa Bay and Sarasota Bay had lost 46% and 15%, respectively, of their seagrass coverage between 1950 and the 1980s. However, over the period of 1999 to 2016, the largest of the six estuaries, Tampa Bay, added 408 ha of seagrass per year, while the remaining five estuaries examined in this paper added approximately 269 ha per year. In total, seagrass coverage in these six estuaries increased 12,171 ha between the 1980s and 2016. Focused resource management plans have held the line on nitrogen loads from non-point sources, allowing seagrass resources to expand in response to reductions in point source loads that have been implemented over the past few decades.

1. Introduction

Seagrasses have long been recognized as important coastal resources. Early studies focused on the habitat value of seagrass meadows for recreational and commercial important species of finfish and shellfish (e.g., Heck et al., 2003). Additionally, the role of seagrass meadows in stabilizing sediments and reducing rates of shoreline erosion has been noted (e.g., Fonseca and Cahalan, 1992). Seagrass meadows have also been shown to play an important role in the sequestration of carbon either through direct burial of biomass (i.e., Duarte et al., 2010; Fourqurean et al., 2012; Greiner et al., 2013; McLeod et al., 2011) or indirectly through bicarbonate sequestration (i.e., Smith, 1981; Burdige and Zimmerman, 2002; Burdige et al., 2010; Tomasko et al., 2016). The ability of seagrass meadows to offset, at least on a local to regional level, the impacts of ocean acidification, has also been documented (i.e., Unsworth et al., 2012; Yates et al., 2016) as well as other benefits (i.e., Unsworth et al., 2012; Sherwood et al., 2017).

Unfortunately, a combination of direct and indirect impacts has resulted in losses of seagrass meadows on a global scale (Orth et al., 2006; Waycott et al., 2009). Environmental degradation and seagrass loss has been documented in great detail in Botany Bay, Australia (Larkum, 1976), Cockburn Sound, Australia (Cambridge and McComb, 1984; Silberstein et al., 1986), the French Mediterranean Sea (Bourcier, 1986), and the Chesapeake Bay, USA (Kemp et al., 1983; Orth and Moore, 1984). Even in Cancun, Mexico, which was developed with a focus on water-based tourism, impacts to seagrass meadows had been documented due to degraded water quality (Reyes and Merino, 1991).

Although the scientific literature is replete with examples of environmental degradation of nearshore waters due to human activities, there are also numerous examples of environmental restoration after pollution sources have been adequately addressed. In Kaneohe Bay, Hawaii (USA) Hunter and Evans (1995) documented the degradation and eventual recovery of water quality and coral communities due to the discharge and subsequent removal of nutrient-enriched wastewater. In the coastal waters of Adelaide, Australia, Bryars and Neverauskas (2004) documented the recovery of seagrass meadows after the cessation of sewage discharges into local waters. In Gunston Cove, Virginia (USA), Jones and Krauss (2009) documented a reduction in algal blooms, a subsequent increase in water clarity, and the eventual increase in the health of aquatic communities in response to an 80% reduction in point source nutrient loads. In the Wadden Sea, van Beusekom (2010) documented improvements in water quality and the health of aquatic communities in response to nutrient load reductions over the prior 40 years.

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In Southwest Florida, much research has focused on relationships among urban development, changing land use patterns, pollutant loads, estuarine water quality, and historical losses of seagrass coverage (i.e., Lewis et al., 1985; Lewis, 1989; Haddad, 1989). In Tampa Bay, Florida (USA), a 90% reduction in point source nitrogen loads has resulted in a substantial improvement in water quality and overall ecosystem health (e.g., Johansson, 1991; Johansson and Greening, 2000; Tomasko, 2002; Greening and Janicki, 2006; Greening et al., 2016; Sherwood et al., 2017). Similar ecosystem recovery has been documented for Sarasota Bay in response to similar reductions in point source nutrient loads (Tomasko et al., 2005).

Tomasko et al. (2005) compared and contrasted the status and trends in seagrass coverage, rainfall, and pollutant loads in four contiguous Southwest Florida estuaries – Tampa Bay, Sarasota Bay, Lemon Bay and Charlotte Harbor. At that time, recovery of seagrass coverage in Tampa and Sarasota Bays was noted, as well as the conclusion that such a trend was likely due to reductions in bay-wide nutrient loads, rather than regional trends in rainfall or other climatic phenomena. This paper provides an update on those seagrass trends with more than a decade of additional seagrass mapping efforts, and includes information on the status and trends of seagrass coverage in two additional and contiguous estuaries – St. Joseph Sound and Clearwater Harbor.

2. Materials and methods

2.1. General description of locations

For purposes of the present paper, the following estuaries will be considered: 1) St. Joseph Sound, 2) Clearwater Harbor, 3) Tampa Bay, 4) Sarasota Bay, 5) Lemon Bay, and 6) Charlotte Harbor (Fig. 1). The region "Charlotte Harbor" will include only those areas north of 26°40′ N latitude.

The climate in this portion of Southwest Florida is subtropical, with warm, wet summers and mild, dry winters. Annual average air temperatures range between 21 and 24 °C, and mean annual rainfall ranges between 136 and 144 cm year^{-1}, with more than half that amount occurring during the typical wet season of June to September (Southwest Florida Water Management District, 2018).

While in immediate proximity to one another, these estuaries vary considerably in terms of the area of open water, total watershed area, and the ratio of watershed to open water (Table 1).

Watershed sizes range from well over 5000 km^2 for both Charlotte Harbor and Tampa Bay to < 200 km^2 for both Lemon Bay and Clearwater Harbor. In terms of their open water area, Tampa Bay is nearly three times as large as Charlotte Harbor, which is more than twice the size of the next largest system – Sarasota Bay. The ratios between the watershed and the open water into which their watersheds drain differ by nearly an order of magnitude. Clearwater Harbor and Sarasota Bay have < 3 km^2 of land draining into every square kilometer of open water, while > 25 km^2 of land drain into every square kilometer of open water in Charlotte Harbor. In terms of the influence of its watershed (expressed as the watershed to open water ratio) Charlotte Harbor is four times as affected as Tampa Bay, which is more than twice as affected by its watershed as Sarasota Bay and Clearwater Harbor.

2.2. Seagrass mapping techniques

Since 1988, estimates of seagrass area, or coverage, have been derived from photointerpretation of aerial imagery acquired under strict protocols (Tomasko et al., 2005). However, resource managers also desired estimates of coverage from before 1988. In St. Joseph Sound, Clearwater Harbor, Tampa Bay and Sarasota Bay, seagrass maps have been generated from aerial imagery collected over a series of flights from 1948 to 1950 and are referred to as "1950" seagrass maps. Tampa Bay and Charlotte Harbor also have seagrass maps for the year 1982. Based on assessments of water quality and pollutant loads, 1950 is considered to represent reference conditions for seagrass distribution, as it appears that seagrass meadows were widely distributed throughout the region (and minimally impacted at that time). In contrast, the years 1982 or 1988 represent degraded conditions, as pollutant loads were at or close to their highest levels and water quality was typically much worse (at least in Tampa and Sarasota Bays) than it was in 1950 (i.e., Tomasko et al., 2005; Greening et al., 2016). For Charlotte Harbor and Lemon Bay, 1950 seagrass estimates were viewed as potentially suspect based on the difficulty of photointerpretation in some areas.

Seagrass maps for 1950 and 1982 were previously produced via photointerpretation of 1:24,000 scale aerial photographs (Tampa Bay Regional Planning Council, 1986; Haddad, 1989). Starting in 1988, the SWFWMD has managed a long-term seagrass mapping program for Tampa Bay, Sarasota Bay, Lemon Bay and Charlotte Harbor. In 1999, the mapping effort was expanded to cover St. Joseph Sound and Clearwater Harbor. The details of the seagrass mapping techniques are discussed in Tomasko et al. (2005) and Sherwood et al. (2017). Starting in 2004, aerial photography and subsequent photointerpretation transitioned from scanned true colour film media to digitally-acquired aerial imagery.

Since 1988, approximately biennial seagrass coverage estimates have been produced based on imagery acquired during the autumn to winter months, as this is the typical dry season in Southwest Florida. The dry season, with lower runoff, is associated with a generalized increase in water clarity in coastal waters, allowing for the acquisition of imagery more likely to be able to pick up the offshore, deeper margins of existing seagrass meadows. Photographic signatures are mapped using two broad categories, patchy and continuous. Polygons mapped as patchy seagrass have seagrass in approximately 25 to 75% of their boundaries, while polygons categorized as continuous have > 75% seagrass coverage within their boundaries. Up to 2012, the minimum mapping unit was set at approximately 0.2 ha in size. Due to the move to digital imagery, this minimum mapping unit was reduced to 0.1 ha starting in 2014.

After the acquisition of aerial photography, field work is conducted to improve the photointerpretation, with special attention focused on areas where the signature is not particularly clear as to whether it represents seagrass, macroalgae, or a combination of the two. After the maps have been generated, the final product is not accepted unless there is at least 90% concurrence of seagrass presence between field ground-truthed points randomly selected from within the created seagrass maps and the classification of those locations. The coverage of more diminutive species of seagrass, such as species within the genus Halophila, are not captured through the use of aerial photography. Fortunately for this effort, species of Halophila are only rarely encountered in local waters, as documented in Tampa Bay (Tomasko et al., 2016).

2.3. Rainfall

The SWFWMD collects and/or compiles rainfall data from 370 gage sites throughout its approximately 28,000 km^2 jurisdictional area, which includes all of the estuaries in this study. Data are available for various periods of record, although most regions have one or more rainfall gage sites that date back to 1915. Rainfall data were combined for all stations throughout each estuary's watershed. For St. Joseph Sound and Clearwater Harbor, rainfall data from the Tampa Bay watershed were used, as the rainfall record is more complete for that region. For Sarasota and Lemon Bays, rainfall data were combined, since these watersheds are relatively small, compared to Tampa Bay and Charlotte Harbor. For Charlotte Harbor, rainfall data were combined from throughout the Peace River watershed, which is the largest (ca. 6000 km^2) source of freshwater inflow to the estuary.