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Long range transport and carbon and nitrogen dynamics of floating seagrass wracks in Greater Florida Bay

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ABSTRACT

Floating aggregations of seagrass wrack can serve as an ecological "hot spot" contributing to the survival of many species in the form of habitat and food source. Considerable research has been conducted on seagrass wrack that is washed ashore, but here we demonstrate that large amounts of floating wrack produced in Greater Florida Bay can be advected great distances from their source, remain buoyant for weeks, and provide a nutrient subsidy into surrounding waters. Drifters tracking the location of floating *Syringodium filiforme* wracks revealed that movement of the wrack is strongly correlated to wind speed with total daily movement ranging from 10 to 40 km d^{-1}. In mesocosm experiments, shedding followed an exponential model with highest rates estimated for loose aggregations of *S. filiforme* (-0.124 d^{-1}) compared to *Thalassia testudinum* (-0.047 d^{-1}). Aggregated whorled *S. filiforme* wrack found offshore had an order of magnitude lower shedding with a rate of -0.013 d^{-1} suggesting it could remain buoyant for several months. Both wrack and the floating macroalgae *Sargassum* sp. released considerable amounts of dissolved organic carbon (DOC) and colored dissolved organic material (CDOM) daily into the dark mesocosm treatments. CDOM represented a constant proportion of the DOC exudate with a spectral slope suggestive of humic materials. *Sargassum* sp. produced twice as much DOC and CDOM compared to seagrass wrack. No net release of dissolved nitrogen was measurable in the treatments during the first 5 to 6 days while vegetation was photosynthetically viable, but particulate organic matter increased in the treatments consistent with the growth of bacterioplankton (C:N ~7). Similar to *Sargassum sp.*, seagrass wrack can be advected offshore and serve as a carbon and nitrogen source for organisms in oligotrophic waters.

1. Introduction

Seagrass ecosystems serve to interconnect marine and terrestrial ecosystems through passive and active transport of nutrients, carbon, detritus, prey and consumers (Heck et al., 2008). An important element of this interconnection is through the production and transport of seagrass detritus from one habitat to another. As seagrass meadows age, senesce, and interact physically with the environment around them, leaves may break off from the beds and either sink to the seafloor surrounding the plants, or float to the surface. Due to the high primary productivity and turnover rates of seagrass leaves (Zieman et al., 1989), considerable amounts of leaves are shed from the meadows and can be transported away from the beds by currents and waves (Davis III et al., 2004; Mateo et al., 2006; Duarte and Krause-Jensen, 2017). Large aggregations of floating vegetation called "seagrass wrack" can be formed (Dierssen et al., 2015) and the biomass is ultimately exported to the seafloor or washed ashore on beaches. Many studies have quantified nutrient subsides from wrack to beach communities (Coupland et al., 2007; Dugan et al., 2011) and the deep sea (Vetter and Dayton, 1998, 1999), but less is known about the habitat structure and nutrient dynamics of floating seagrass wrack, particularly in surface waters devoid of nutrients (Duarte and Krause-Jensen, 2017).

Although reports are few, different species of seagrass appear to export different amounts of biomass ranging from 0 to 100% of total production (Mateo et al., 2006). The morphology and buoyancy of the leaves can determine the duration of the floating wrack with long, bulky leaves sinking soon after shedding and light, thin leaves staying afloat for longer period of time (Mateo et al., 2006). For example, a study on adjacent beds of broad flat-leafed *Thalassia testudinum* Banks & Sol. ex Koenig (turtle grass) and thin cylindrical-leafed *Syringodium filiforme* Kuetz (manatee grass) from a site in the U.S. Virgin Islands found that *T. testudinum* exported only 1% of its leaf production, while *S. filiforme* exported 60–100% of its biomass (Zieman et al., 1979). Our study evaluates floating wrack produced in Greater Florida Bay which is home to large seagrass meadows of both *T. testudinum* and *S. filiforme* (Fourqurean and Robblee, 1999; Fourqurean et al., 2001; McPherson

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et al., 2011; Gilerson et al., 2013).

Weather, tides, and the degree of bed exposure can determine the intensity of the physical forces that serve to export seagrass leaves from the beds to distant locations offshore (Thomas et al., 1961; Davis III et al., 2004; Mateo et al., 2006). Dierssen et al. (2015) found that strong southerly winter winds in Greater Florida bay advected considerable amounts of seagrass wrack comprised predominantly of *S. filiforme* from the dense meadows in Greater Florida Bay to oligotrophic Atlantic Ocean waters. Over time, the leaves became more aggregated into patches and could be found in long windrows produced by downwelling lobes of Langmuir circulation. In addition, the wrack observed floating over the continental shelf contained aggregates of leaves occurring in whorled structures. During the winter storm season, considerable litter from mangroves and seagrass beds can be advected from southeastern Everglades National Park (Davis III et al., 2004). Off the Tasmanian coast, Thresher et al. (1992) similarly found offshore transport of seagrass detritus coincided with strong winterly storms (Thresher et al., 1992). Winds and turbulence associated with the 1960 Hurricane Donna produced over 1 million kg of *T. testudinum* wrack washed ashore along the beaches in Biscayne Bay (Thomas et al., 1961).

Floating at the sea surface, seagrass wrack can serve as a habitat or a metabolic "hot spot" similar to other floating vegetation such as floating macroalgae *Sargassum* sp. (hereafter *Sargassum*). In tropical waters, pelagic *Sargassum* wrack is an important home to many species of organisms, including juvenile fish species, many invertebrate species including shrimp, crabs, and nudibranchs, and epiphytic organisms like hydroids, bryzoans, and algae (Dempster and Kingsford, 2004), as well as recreationally and commercially important fish species like mahi, snapper, and grouper (Coston-Clements et al., 1991). Thresher et al. (1992) is one of the only studies to report on the trophic impacts of floating seagrass wrack. Through indirect lines of evidence, they report that microbial decomposition of floating seagrass played a pivotal role in the coastal planktonic food chain (Thresher et al., 1992). This study aims to bridge this knowledge gap on trophic impacts of wrack by examining the degradation rate and capacity for nutrient regeneration of Florida Bay wracks composed of a variety of primary producers. Travel time of wracks and the shedding rate of seagrass beds were also examined to inform understanding of the life cycle of a floating seagrass wrack.

2. Methods

2.1. Study region

Field observations and collections were conducted in Greater Florida Bay during January 2014 with experimental work conducted at the Keys Marine Laboratory on Long Key, Florida, United States. Greater Florida Bay is a shallow estuary grading into a tropical lagoon, influenced by the Gulf of Mexico and the Everglades (Fig. 1). The south Florida region, which includes Greater Florida Bay and the Atlantic Ocean side of the Florida Keys, hosts over 10,000 km^2 of seagrass. *Thalassia testudinum* has an estimated area of 6400 km^2 and *S. filiforme* of 4400 km^2 (Fourqurean et al., 2001). Winds in Greater Florida Bay during the winter are higher than during the rest of the year, and usually blow from the northeast (Schomer and Drew, 1982), providing ideal conditions for estimating the maximum transport of wrack from Greater Florida Bay to the Atlantic side of the Keys.

2.2. GPS drifters

The potential transport of floating mats of wrack from Florida Bay to the Atlantic side of the Keys was estimated during three deployments of Lagrangian surface drifters equipped with GPS transmitters. For each deployment, three drifters were deployed simultaneously over a dense *S. filiforme* bed in Greater Florida Bay, north of Long Key (24.900266° N, −080.920293° W). Deployments continued until drifters ran aground or advected into the Atlantic Ocean. Drifters were deployed on January 6, 11, and 17. The neutrally buoyant drifters were constructed of inverted 19 L plastic buckets, foam, lead weight, and outfitted with NOAA GPS trackers provided by the Northeastern Regional Association of Coastal and Ocean Observing Systems (NERACOOS) program which broadcast their position every half hour (http://www.neracoos.org/drifters). The drifters tracked the upper meter of the water column including wind drag. Wind speed and direction were obtained from the National Data Buoy Center, station NFBF1(25.084°N 81.096°W), owned and maintained by the University of South Florida in Northwest Florida Bay. Location of drifters relative to floating rafts of wrack were noted upon retrieval.

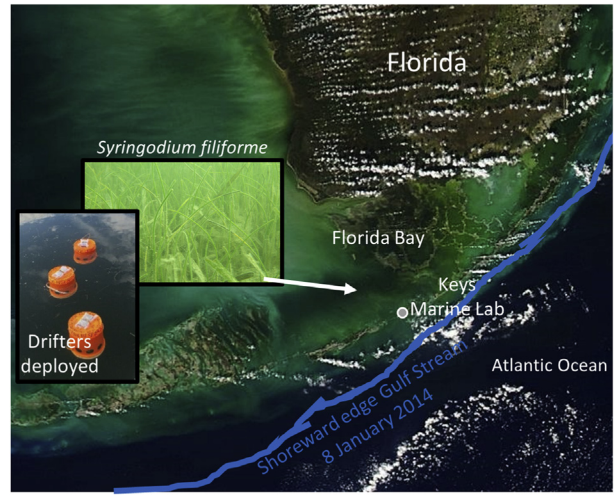

Fig. 1. A. Pseudo-true color imagery from the MODIS Aqua satellite showing the location of Keys Marine Laboratory where the experimental study site was located and the dense *Syringodium filiforme* beds where the GPS-tracking drifters were deployed at the sea surface. The dark colors from the satellite are indicative of high light absorption from the dense seagrass beds. The shoreward edge of the Gulf Stream traveling northward is shown in blue. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Floating mats originating from the Florida Bay seagrass beds north of Long Key were assumed to transit to the Atlantic Ocean in less than two weeks, leaving the Florida Keys National Marine Sanctuary. Beyond this time, floating mats were assumed to enter deep water (depth > 100 m); this assumption determined the eleven-day to fourteen-day length of the experiments. Within Florida Bay, floating mats are composed of loose leaves not bound to one another. In contrast, groups of whorled clumps of *S. filiforme* (~20 cm x ~10 cm, ~300 g wet weight) were found floating in the Looe Key Management Area, located on the Atlantic side of the Keys.

2.3. Temporal loss of biomass from wracks

Floating mats of wrack shed leaves which sink to the seafloor, providing an external source of nutrients as the mats travel; the focus of this experiment was determining the shedding rate of wrack as it transits from Florida Bay to the sensitive habitats located on the Atlantic side of the Florida Keys National Marine Sanctuary. Floating wrack was collected from the Keys Marine Lab seawall (24.825875° N, −080.814375° W) freshly pushed in from Florida Bay waters to the north. The wrack collected from this area is representative of wrack leaving Florida Bay and traveling to the Atlantic Ocean.

Three replicates were assessed for each of three treatments. A similar volume of wrack was used for each treatment replicate to roughly cover an area equivalent to the experimental enclosure. The first treatment consisted of the collected wrack without any separation of species or removal of macroalgae, with average wet weight of