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Tropical seagrass species tolerance to hypersalinity stress

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Abstract

The long-term sustainability of seagrasses in the subtropics and tropics depends on their ability to adapt to shifts in salinity regimes, particularly in light of present increases in coastal freshwater extractions and future climate change scenarios. Although there are major concerns world-wide on increased salinity in coastal estuaries, there is little quantitative information on the specific upper salinity tolerance of tropical and subtropical seagrass species. We examined seagrass hypersalinity tolerance under two scenarios: (1) when salinity is raised rapidly simulating a pulsed event, such as exposure to brine effluent, and (2) when salinity is raised slowly, characteristic of field conditions in shallow evaporative basins; the first in hydroponics (Experiments I and II) and the second in large mesocosms using intact sediment cores from the field (Experiment III). The three tropical seagrass species investigated in this study were highly tolerant of hypersaline conditions with a slow rate of salinity increase (1 psu d^{-1}). None of the three species elicited total shoot mortality across the range of salinities examined (35–70 psu over 30 days exposures); representing in situ exposure ranges in Florida Bay, a shallow semi-enclosed subtropical lagoon with restricted circulation. Based on stress indicators, shoot decline, growth rates, and PAM florescence, all three species were able to tolerate salinities up to 55 psu, with *Thalassia testudinum* (60 psu) and *Halodule wrightii* (65 psu) eliciting a slightly higher salinity threshold than *Ruppia maritima* (55 psu). However, when salinity was pulsed, without a slow osmotic adjustment period, threshold levels dropped 20 psu to approximately 45 psu for *T. testudinum*. While we found these three seagrass species to be highly tolerant of high salinity, and conclude that hypersalinity probably does not solely cause seagrass dieoff events in Florida Bay, high salinity can modify carbon and O_2 balance in the plant, potentially affecting the long-term health of the seagrass community.

Keywords: Salinity; Hypersalinity; Seagrass; *Thalassia testudinum* Banks ex Konig; *Halodule wrightii* Aschers.; *Ruppia maritima*; Osmotic adjustment

1. Introduction

Seagrasses are keystone species in many shallow lagoons and estuaries providing a complex habitat and high rates of primary production for ecologically and economically important higher consumers (Bell and Pollard, 1989; Heck et al., 2003; Bloomfield and Gillanders, 2005). The long-term sustainability of seagrasses, particularly in the subtropics and tropics, depends on their ability to adapt to shifts in salinity regimes influenced by anthropogenic modifications of upstream hydrology, as well as long-term temperature increases predicted to be associated with future climate change (Short and Neckles, 1999). Seagrass species in the subtropics may be more susceptible to moderate increases in heat loads because they already exist at their upper physiological tolerance to temperature and salinity, although few studies have confirmed upper thresholds. Susceptibility to these stressors is most pronounced in shallow lagoons with restricted circulation. For example, Florida Bay (1800 km^{-2}), a shallow semi-enclosed lagoon in South Florida, reaches salinities greater than 35 psu almost every year in the recent past (1989–2002; Fig. 1), and has been found to sustain hypersaline conditions year-round during periods of drought (Fig. 1; Boyer et al., 1999; Fourqurean and Robblee, 1999). In addition to natural periodicities of drought in the subtropics, coastal freshwater extractions reduce freshwater inflows to estuarine systems, important for balancing high rates of evaporation. For example, the diversion and withdrawal of freshwater from the Caloosahatchee River on the west coast of Florida has resulted in negative ecological consequences for the Caloosahatchee Estuary, such as highly variable salinity and loss of submerged aquatic vegetation (Doering et al., 2002). In Florida Bay, hydrological modifications in the highly engineered Greater Everglades system significantly influence the amount and

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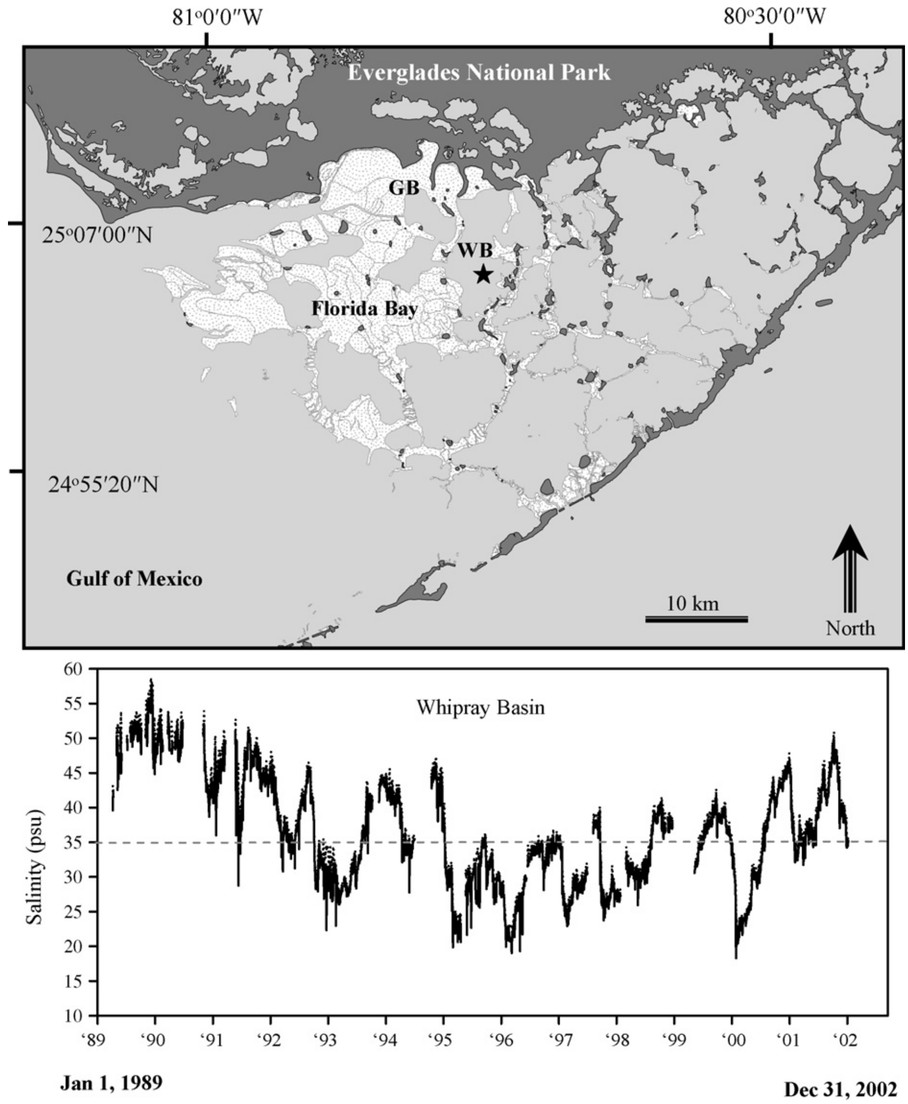

Fig. 1. Seagrass collection sites in Whipray Basin (WB) and Garfield Bight (GB) in north central Florida Bay at the lower terminus of the Florida peninsula south of the freshwater everglades (upper panel). Long-term daily minimum and maximum salinity data for WB from 1989 to 2002 (lower panel).

timing of freshwater flows received by the Bay (Light and Dineen, 1994; Nuttle et al., 2000). Upstream hydrologic changes, combined with the seasonality of rainfall, define the salinity envelope of these and other systems and determine seagrass exposure to hypersaline conditions.

Although there are major concerns world-wide on the potential and in some cases present increases in salinity of coastal estuaries (Short and Neckles, 1999), there is very little quantitative information on the specific upper salinity tolerances of tropical and subtropical seagrass species. Salinity in natural estuarine and lagoon systems increase at slow rates due to the synergistic effects of evaporation and restricted circulation, such as in Florida Bay (Nuttle et al., 2000), Shark Bay, Western Australia (Walker et al., 1988), and Baffin Bay, Texas (Cotner et al., 2004). However, desalination plants that use reverse osmosis for fresh water supply, such as along the Mediterranean and elsewhere in the world, have resulted in hypersaline effluent (44–90 psu) being pulsed into coastal systems (Fernandez-Torquemada and Sanchez-Lizaso, 2005). Thus, it is important to evaluate seagrass salinity tolerance to both pulsed and a slow rates of salinity increase.

One of the limitations in defining specific upper salinity tolerances in coastal marine environments is the difficulty of conducting controlled field experiments, particularly in subtropical and tropical environments where rainfall is spatially variable and salinities are highly dynamic. In addition, interactive stressors such as high temperature can confound the determination of a hypersalinity response in the field where heat loads drive evaporation and hypersaline conditions. Thus, we used a highly controlled mesocosm experimental approach to articulate the upper salinity tolerances of three dominant tropical seagrass species, *Thalassia testudinum* Banks ex König, *Halodule wrightii* Aschers. and *Ruppia maritima* L. Although we recognize that *R. maritima* is not a true seagrass, it is a dominant submerged macrophyte found at the freshwater Everglades-Florida Bay marine ecotone, a zone that becomes hypersaline during droughts. This seagrass species is also predicted to increase in distribution in Florida Bay with greater