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Fragment production and recruitment ecology of the red alga *Laurencia poiteaui* in Florida Bay, USA

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ABSTRACT

In 2000 and 2001, *Laurencia poiteaui* (Rhodophyta, Ceramiales) was the dominant organism in the patchy seagrass beds off Long Key in Florida Bay. Earlier research established that asexual fragmentation is the predominant mode of reproduction in this benthic drift macroalga, yet no studies documenting post-fragment success have been published to date. To better understand fragmentation, and ultimately recruitment of *L. poiteaui*, we examined fragment: 1) accumulation rates, 2) variability, 3) dispersal distances, and 4) attachment rates. In July 2000 and July 2001, the majority (>50%) of the algal fragment pool near Long Key was comprised of *L. poiteaui*. The length of these fragments ranged from 0.7 to 15.7 cm, but >75% of the collected fragments were <6 cm. Short dispersal distances (<7 cm within beds of the seagrass *Thalassia testudinum* and<30 cm over sand after 7 days) and fast attachment rates (<48 h) suggest that most fragments (3–4 fragments/day/m^2) recruit locally. Attachment success of *L. poiteaui* fragments was high in both laboratory and field (95.5% and 88.2%, respectively). Sand and silt decreased the attachment rate of *L. poiteaui*, but the presence of a terminal apical tip had no influence. The combination of high fragment production, slow dispersal rates, and rapid attachment rates of *L. poiteaui* ultimately suggests that vegetative fragmentation plays an important role in the abundance of this macroalga in the calm, shallow areas of southeastern Florida Bay.

1. Introduction

Several species of *Laurencia* inhabit the patchy seagrass habitat of southeastern Florida Bay (Chiappone and Sullivan, 1994; Wick, 2002; Zieman et al., 1989). High abundance and the benthic drift lifestyle of *Laurencia* spp. benefit a diversity of marine organisms in these relatively calm waters by providing: 1) productive nursery habitat (Childress and Herrnkind, 1994; Davis and Dodrill, 1989; Forcucci et al., 1994; Fourqurean and Robblee, 1999; Herrnkind and Butler, 1994; Holmquist, 1994; Marx and Herrnkind, 1985a, 1985b), 2) post-larval metamorphic cues and shelter to the economically important queen conch *Strombus gigas* and the Caribbean spiny lobster *Panuliris argus* (Davis and Stoner, 1994; Davis et al., 1990; Herrnkind and Butler, 1994), and 3) a primary mode of dispersal and food source for many fishes and invertebrates, especially brooders and organisms with short planktonic life-history stages (Holmquist, 1994; Stoner and Livingston, 1980).

The benthic drift lifestyle of one of the most ubiquitous species of *Laurencia* in Florida Bay, *Laurencia poiteaui* (Lamouroux) Howe, is not commonly seen on coral and sabellariid wormrock reefs in central and south Florida and is likely advantageous for this population. Smaller individuals, perhaps those able to drift easily with the current, tend to epiphytize other benthic organisms in Florida Bay (Frankovich and Fourqurean, 1997; Humm, 1964; Wick, 2002). In 2001, *L. poiteaui* was documented to epiphytize most (70%) of the benthic macroalgae and sponges in Florida Bay near Long Key (Wick, 2002). One reason for the abundance of both drift and secondarily attached forms of this species in Florida Bay is its ability to reproduce via vegetative fragmentation (Cruz-Adames and Ballantine, 1996; Josselyn, 1975, 1977; Wick, 2002).

Vegetative fragmentation, the ability of algal fragments separated from the adult thallus to settle, secondarily attach, and grow as a clone, is an important reproductive strategy commonly used by marine macroalgae (Cecere et al., 2011; Kilar and McLachlan, 1986; Smith and Walters, 1999; Walters et al., 2002). Many species capable of fragmenting, or cloning, are particularly efficient at establishing new locations through rapid attachment rates and fragment longevity (Ceccherelli and Piazzi, 2001; Kilar and McLachlan, 1986). These include the well-known examples of algal invasions like the green alga *Caulerpa taxifolia* in the Mediterranean Sea, which was later introduced to California and Australia (Ceccherelli and Cinelli, 1999; Walters, 2009); *Caulerpa brachypus*, a Pacific native, which has increasingly been documented on several of the artificial and natural reefs in south Florida (Lapointe and Bedford, 2009); *Hypnea musciformis*, a red alga that was intentionally introduced to O'ahu from Florida for commercial purposes in 1974 (Doty, 1961; Steneck

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and Carlton, 2001; Russell, 1992); and *Acanthophora spicifera*, a red alga found throughout the Hawaiian Islands thought to arrive as a passenger on a fouled ship hull from Guam in 1950 (Doty, 1961). In the Florida Keys, efficient cloners tend to persist throughout the year at relatively high abundances, such as *Dictyota* spp. along the reef tract and *Laurencia* spp. in Florida Bay (Beach et al., 2003; Herren et al., 2006; Walters and Beach, 2000; Wick, 2002; Zieman et al., 1989).

Although known to reproduce sexually in Quintana Roo, Mexico (Fujii et al., 1996), Josselyn (1975, 1977) documented vegetative fragmentation to be the primary mode of dispersal of *L. poiteaui* in Card Sound, FL, northeast of Florida Bay. This species maintains continuous vegetative growth and fragmentation, but exceptionally warm water temperatures weaken the thallus and promote higher rates of fragmentation during the summer months (Biebl, 1962; Josselyn, 1977; Kilar and McLachlan, 1986; Thorhaug, 1971). The high summer fragmentation rates are followed by late summer and early fall rain events conveying land-based sources of nutrients to the phosphorus-limited waters of Florida Bay (Boyer et al., 1999; Fourqurean et al., 1993; Humm, 1964; Lapointe et al., 1992). Nutrient inputs were shown to play an important role in the growth, survival, and photosynthetic performance of drifting fragments by Vermeij et al. (2009). Lapointe (1989) also reported that *L. poiteaui* collected in the nearby Content Keys had high capacities for the phosphorus-extracting enzyme alkaline phosphatase and that its growth was stimulated with phosphorus enrichment. Following the flush of land-based nutrient associated with the wet season, the water temperatures in south Florida cool to the optimal temperature range (20–25 °C) for growth in this species (Thorhaug, 1971). Thus, if summer-generated fragment survivorship is high, then fragments have several months to re-attach and start vegetative growth during the fall when phosphorus inputs increase, water temperatures drop, and growth rates increase again.

Over time, the process of vegetative fragmentation can influence population structure and dynamics (Cecere et al., 2011; Coffroth and Lasker, 1998). Fragments, which are genetically identical to the parent thalli, may: 1) help reduce the chances of genotypic mortality (Coffroth and Lasker, 1998), 2) survive unpredictable environmental changes that are potentially lethal to the entire thalli, and 3) have a better likelihood of reaching new habitats and increasing local populations; potentially making fragmenting species more competitive than algal species that have not evolved this life-history strategy (Cecere et al., 2011). Although fragmentation has been documented as an important life-history trait in the genus *Laurencia* (Cecere et al., 2011; Cruz-Adames and Ballantine, 1996; Josselyn, 1975, 1977), little research has been conducted to understand the recruitment process of these fragments in the field. Consequently, the focus of this study was to better understand fragment: 1) accumulation rates, 2) variability, 3) dispersal distances, and 4) attachment rates.

2. Methods

2.1. Study location and study organism

Research was conducted at the Florida Institute of Oceanography's Keys Marine Laboratory (KML), located on Long Key, in June and July 2000 and 2001. Laboratory experiments were performed in continuously running outdoor seawater tables supplied by water drawn from Florida Bay immediately adjacent to KML. Because of the close proximity of the field study site to KML, the salinity and the temperature of the water in the experimental seawater tables and the field site were similar. Field experiments were conducted using SCUBA at one shallow (3 m) backreef site in Florida Bay located approximately 1 km northeast of KML, 0.5 km east of Old Dan Bank, and 2.5 km southwest of Fiesta Key (24° 50.025′ N; 80° 49.016′ W; Fig. 1). Due to low visibility (<1 m), all field experiments were established along a fixed 100 m × 4 m band transect (2 m on either side of the center line). Referred to as the Atlantic sub-environment, this region of the Bay has significantly more sponges, hard corals and gorgonians than other Florida Bay sub-environments (Fourqurean and Robblee, 1999). However, this area was dramatically altered between 1991 and 1995 when a bloom of

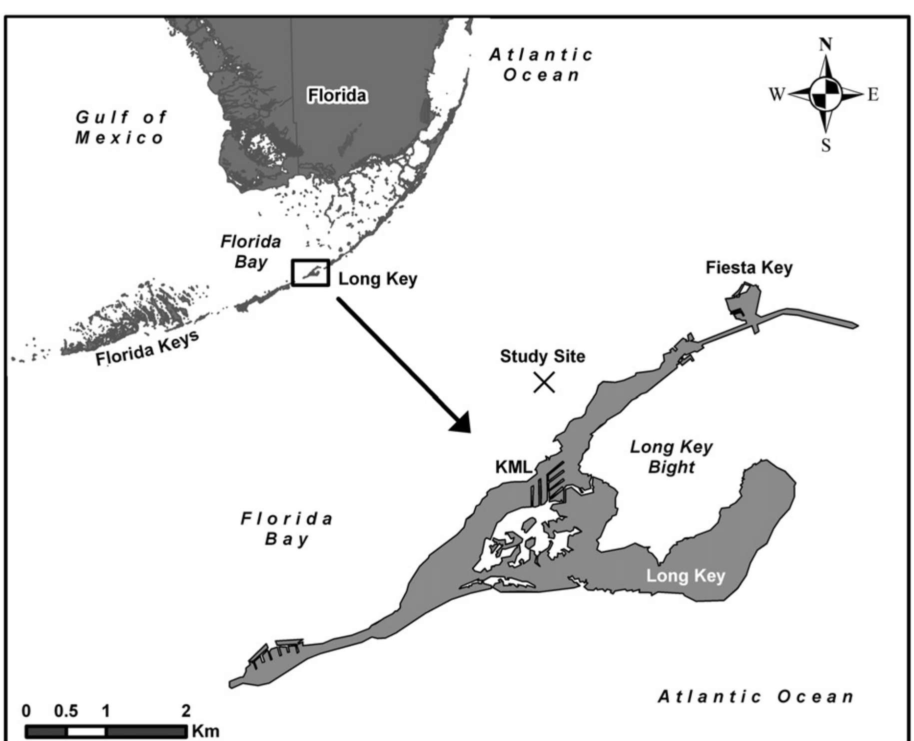

Fig. 1. Location of the study site 1 km northeast of the Florida Institute of Oceanography's Keys Marine Lab (KML) on Long Key in the Florida Keys.