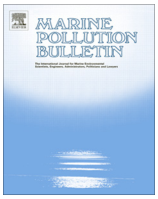
Marine Pollution Bulletin xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul



Contrasting recovery of shallow and deep water seagrass communities following climate associated losses in tropical north Queensland, Australia

Michael A. Rasheed *, Skye A. McKenna, Alexandra B. Carter, Robert G. Coles

James Cook University, Centre for Tropical Water & Aquatic Ecosystem Research, PO Box 6811, Cairns, QLD 4870, Australia

ARTICLE INFO

Keywords:
Seagrass
Loss
Recovery
Climate
Seed
Reproduction

ABSTRACT

Tropical seagrass decline and recovery from severe storm impacts was assessed via quarterly measurements of seagrass biomass, species composition and experimental investigations of recovery in north Queensland. Shallow and deep seagrass meadows suffered major declines. Significant recovery in the two years following loss only occurred at deeper sites. *Halophila* spp. in deep water areas had a high capacity for recovery through the availability of seed banks. In contrast, the shallow species did not recover quickly from experimental disturbance, had poor seed reserves and relied on asexual propagation. The potential for shallow species to recover rapidly from widespread losses was limited as seed banks were limited or non-existent. Understanding inter- and intra-specific differences in seagrass recovery and how this interacts with location is critical to predict the consequences of climate events to tropical seagrasses. This is especially important as more frequent severe storms are predicted as a consequence of climate change.

1. Introduction

In recent years wide spread loss of seagrass meadows in the Great Barrier Reef (GBR) caused by weather and climate events have emphasized the need to understand the processes and timing of seagrass recovery (McKenzie et al., 2012). The frequency and severity of storms and climate conditions, including multiple above-average wet seasons in the tropics is, likely to increase as a consequence of climate change (Harley et al., 2006; Crabbe et al., 2008). This has the potential to substantially impact GBR seagrasses and reduce their capacity for recovery. The mechanisms for climate events to cause seagrass loss are relatively well documented (e.g. Campbell and McKenzie, 2004; Preen and Marsh, 1995; Ralph et al., 2007), but the capacity and mechanisms for recovery are poorly understood.

In the southern hemisphere summer of 2010/2011 Queensland, Australia experienced a series of extreme weather events driven by a La Niña weather system. This La Niña system was one of the strongest on record and caused high and prolonged rainfall and flooding. Nearly all rivers within the GBR region produced record flows (Devlin et al., 2012). Major flood plumes were observed across ~39% of the GBR marine park (Devlin et al., 2012). The La Niña also triggered three severe tropical storms that directly affected the north Queensland coast over the summer of 2010/2011: Tropical Cyclone (TC) Tasha (December 2010), TC Anthony (January 2011) and TC Yasi (February 2011). TC Yasi was the first category five cyclone (the most severe category possible) to cross the Queensland coast since 1918. Approximately 98% of intertidal seagrass area was lost in the regions directly affected by TC Yasi's path, and only a few isolated shoots remained in many coastal and reef habitats where long term seagrass cover assessments were conducted (McKenzie et al., 2012).

Queensland's coastal habitats are regularly exposed to flooding and cyclones, but the scale and longevity of the 2010/11 La Niña events were unprecedented. Three of the four summers between 2007 and 2011 in Queensland have had above average rainfall associated with La Niña conditions. Storms and cyclones have the potential to negatively impact seagrass either physically via burial, scouring and direct removal of plants and seed banks (Bach et al., 1998; Campbell and McKenzie, 2004; Preen and Marsh, 1995) or physiologically via light limitation, excess nutrients and low salinity (Bjork et al., 1999; Chartrand et al., 2012; Ralph et al., 2007). Large scale mortality of seagrasses associated with low salinity and higher water temperature caused by flood conditions have previously been documented (McKenzie et al., 2010; Waycott

---

* Corresponding author. Tel.: +61 7 42322010.
E-mail addresses: michael.rasheed@jcu.edu.au (M.A. Rasheed), skye.mckenna@jcu.edu.au (S.A. McKenna), alexandra.carter@jcu.edu.au (A.B. Carter), rob.coles@jcu.edu.au (R.G. Coles).

http://dx.doi.org/10.1016/j.marpolbul.2014.02.013

Please cite this article in press as: Rasheed, M.A., et al. Contrasting recovery of shallow and deep water seagrass communities following climate associated losses in tropical north Queensland, Australia. Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.02.013

et al., 2005). Tropical Queensland seagrasses have a capacity to recover from climate-associated disturbance, returning to pre-impact levels within 4–60 months (Campbell and McKenzie, 2004; McKenzie et al., 2003, 2012; Rasheed, 1999, 2004) although full recovery of some meadows may take longer than 10 years in some instances (Birch and Birch, 1984). The mechanisms for recovery and the variability in timing, however, are often unclear.

Studies have shown a high reliance on asexual colonisation and clonal growth for recovery of many tropical seagrass meadows including experimental investigations in Queensland (Rasheed, 1999, 2004) and examination of small scale disturbances in Florida and the Philippines (Kenworthy et al., 2002; Rollon et al., 1999). However seed banks and seed recruitment are also likely to have a major role in the recovery process, particularly when widespread seagrass losses occur (Hammerstrom et al., 2006). It is likely that there is high variability among species and within species at different locations in their capacity for sexual reproduction and the creation of seed banks. *Halodule uninervis* meadows off Townsville produce dense seed banks (Inglis, 2000), for example, yet meadows of the same species off nearby Cairns have no or limited seed banks (Rasheed, 2004). For the majority of seagrass meadows in the region little is known of their capacity for sexual and asexual reproduction, the investment made in maintaining seed banks, or the temporal variation in seed banks and seed production despite this being critical information in determining their resilience and capacity for recovery from impact.

Because of the stochastic nature in the timing and location of tropical storms and the lack of baseline and monitoring data on seagrass it is difficult to assess the damage to seagrass, the recovery cycle and recovery processes, and to provide advice to coastal management agencies on recovery. Our study uses the results of a long term (2008–2012) monitoring and research program at Abbot Point Queensland, that had been initiated in response to a development proposal. This monitoring program fortuitously enabled both a trend analysis of impacts and recovery of seagrasses, and also the experimental tools to understand the processes occurring. We use this information to contrast the recovery of shallow inshore and deep water seagrass meadows. We examine the relative contribution of asexual and sexual reproduction as mechanisms for recovery among the different seagrass species through manipulative experiments and seed bank assessments that were being undertaken when the storm occurred. Together these studies were used to provide a novel insight into the varying ability and mechanisms of different tropical seagrass meadows to recover from large scale storm related losses.

2. Methods

2.1. Study area

Abbot Point is on the eastern coast of north Queensland, 25 km north-west of Bowen township (Fig. 1). Seagrass monitoring was conducted between Abbot Point and Euri Creek. Abbot Point is located in Queensland's tropical region and typically experiences a summer wet season (December to March) with an average annual rainfall of 890 mm. Air temperatures range from a mean monthly minimum of 13.3 °C in July to a mean monthly maximum of 31.5 °C in January. The Don River drains the watershed that flows into the study area.

Total annual rainfall and local river flow during the study period were well above the long term averages reflecting the strong La Niña weather system during 2010 and 2011 (Figs. 2 and 3).

The offshore and coastal substrate surrounding Abbot Point is open silty/sand. Seagrass communities are the dominant benthic habitat feature, sheltered from oceanic conditions by the Great Barrier Reef (GBR). Eight species of seagrass have been identified in the region with *Halophila* spp. dominating the deeper offshore areas and *H. uninervis* dominating the inshore coastal areas (Lee Long et al., 1993; Rasheed et al., 2005). *H. uninervis* and *Halophila* spp. are considered to be relatively rapid colonisers and all have fast clonal growth rates (Rasheed, 2004). However *Halophila* is a smaller growing species that is shallow rooted with comparatively much smaller stores of energy than *H. uninervis.* As a consequence *Halophila* tends to have a lower resilience to impacts and can be highly seasonal and ephemeral. The seagrass meadows in the study were patchy and variable in density. Seasonal variation of above-ground biomass has been reported for the area with a spring/summer maxima and a winter minima (Unsworth et al., 2010).

2.2. Seagrass sampling

Seagrass above-ground biomass (g DW m^{-2}) and species composition were assessed at five shallow inshore seagrass meadows and three deeper offshore areas approximately quarterly between May 2008 and September 2012. The shallow meadows were dominated by *H. uninervis* and *Zostera muelleri* sub sp. *capricorni* and the deeper offshore meadows by *Halophila decipiens* and *Halophila spinulosa* which are typical assemblages in shallow and deep water habitats in the GBR region.

Sampling sites at shallow meadows (to approximately 6 m below mean sea level (MSL)) were located along transects perpendicular to the shoreline, extending approximately 1 km offshore. Assessments were made at approximately 20–100 m intervals along each transect or where major changes in bottom topography occurred with additional sites sampled randomly between transects. Transects within meadows were placed approximately 100 m apart from each other with the total number of transects dependent on the size of the meadow.

Within each of the three deep water sites (deeper than 6 m below MSL) three replicate blocks were assessed with three 100 m transects randomly placed within each block. Deep water sites were surveyed using a sled towed real time closed circuit television (CCTV) camera system. At each sampling site, the camera system was towed for 100 m at drift speed (approximately one knot) and footage observed and recorded. The camera was mounted on a sled that incorporated a sled net 600 mm wide and 250 mm deep with a 10 mm-mesh aperture. Surface benthos was captured in the net and used to confirm seagrass presence and species composition. The technique ensured a large area of seafloor was observed at each site so that patchily distributed seagrass that typifies deep water habitats in the region could be detected. Ten randomly assigned frames were selected from the video record of each 100 m transect for seagrass biomass assessment.

Seagrass above-ground biomass at each sampling site (shallow) or video frame (deep water) was determined by visually estimating biomass as described by Mellors (1991) and Rasheed and Unsworth (2011). This technique involves an observer ranking seagrass biomass within a haphazardly placed 0.25 m^2 quadrat at each site. Ranks are made in reference to a series of quadrat photographs of similar seagrass habitats for which above-ground biomass has previously been measured. The relative proportion of the above-ground biomass (percentage) of each seagrass species within each survey quadrat was also recorded. Field biomass ranks were converted into above-ground biomass estimates in grams dry weight per square metre (g DW m^{-2}). Each observer ranked a series of calibration quadrats that represented the range of seagrass biomass in the survey. After ranking, seagrass in these quadrats was harvested and the actual biomass determined in the laboratory. A linear regression was calculated between the observed ranks and the measured above-ground biomass for each individual observer. Observer-specific regression equations were

Please cite this article in press as: Rasheed, M.A., et al. Contrasting recovery of shallow and deep water seagrass communities following climate associated losses in tropical north Queensland, Australia. Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.02.013