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15B Seagrasses and seagrass ecosystems

Torres Strait Seagrass Productivity, Climate Change Resilience and Recovery Capacity

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Abstract. The Torres Strait has some of the most extensive seagrass meadows in northern Australia. These meadows support populations of threatened species such as dugong and turtle and commercially important fisheries species. The central Torres Strait region is particularly important and has been referred to as a ‘‘powerhouse’’ for dugong in the Torres Strait because of the extensive seagrass meadows in the area and the high number of dugong they support. The primary production from the extensive seagrass meadows in Torres Strait underpins much of this fisheries and traditional hunting production. Detailed data on seagrass abundance, growth rates, reproductive capacity and community structure were collected at Mabuiag Island, Torres Strait, over a five month period in 2011 to estimate above-ground productivity and carbon assimilated by these meadows. During the same period, manipulative experiments were conducted that aimed to examine seagrass recovery from removal related disturbance, while light, temperature and other water quality parameters were recorded to help determine resilience to climate change. The results of the study are discussed, including implications for how their availability and productivity as a food resource for dugong and turtle changes through time and under changing climate conditions.

Key words: Seagrass, Recovery, Productivity, Resilience.

Introduction

The Torres Strait region covers an area of more than 35,000 km^2 and is located on one of the world’s most extensive continental shelves. It comprises 247 islands, eighteen of which are permanently inhabited. Local island communities in the Torres Strait are deeply connected to their sea country through their culture, economy, spirituality and social way of life. The health of their marine resources has been, and continues to be, vital to Torres Strait Islanders from a subsistence, commercial and cultural point of view.

The importance of seagrasses as structural components of coastal ecosystems is well recognised. Seagrass/algae beds have been rated the third most valuable ecosystem globally (on a per hectare basis) for ecosystem services, preceded only by estuaries and swamps/flood plains (Costanza et al. 1997). The Torres Strait is estimated to contain between 13,425km^2 (Coles et al. 2003) and 17,500km^2 (Poiner and Peterkin 1996) of seagrass habitat, providing critical habitat for commercial and traditional fishery species as well as important food resources for endangered dugong and green turtle populations (Coles et al. 2003; Marsh and Kwan 2008; Sheppard et al. 2008). The largest population of dugongs in the world is in Torres Strait (Marsh et al. 1997, 2002), where the long-standing importance of dugongs for subsistence by Torres Strait Islanders has been traced in archaeological deposits dating back at least 2000 years (Vanderwal 1973). For the Indigenous people of Torres Strait, dugong is the most significant and highest ranked marine food source in the traditional subsistence economy (Nietschmann 1984; Raven 1990; Johannes and MacFarlane 1991; Kwan 2002).

The dynamics of seagrasses in Torres Strait are strongly influenced by natural and anthropogenic pressures. At the Orman Reefs, Torres Strait, the biomass and growth of seagrasses can vary by up to a factor of 3.5 during one year (Rasheed et al. 2008) while in South East Asia they can vary by a factor of four (Brouns 1985; Erftemeijer and Herman 1994; Lanyon and Marsh 1995). There are a variety of factors that influence seagrass meadow biomass, area, and species composition including: physical disturbance (Duarte et al. 1997), herbivory (Klumpp et al. 1993), intraspecific competition (Rose and Dawes 1999), nutrients (Short 1988), seasonality of environmental factors (McKenzie 1994; Mellors et al. 1993) and flooding (Campbell and McKenzie 2004). Studies have shown substantial seagrass dieback (up to 60%) on two occasions in central Torres Strait (Long and Skewes 1996; Marsh et al. 2004). The causes for these diebacks are unclear. Although suggested to be the result of flooding (Long and Skewes 1996), recent investigations have shown that neither the movements of large sandbanks nor turbidity from rivers on the south coast of Papua New Guinea are likely to affect seagrass communities of

Torres Strait on a regional scale (Daniell et al. 2006). Nevertheless, these diebacks have been linked to declines in the dugong population (Marsh et al. 2004).

Whilst we are beginning to gain an idea of the distribution, abundance and productivity contribution of important seagrass habitat in the Torres Strait, a lack of detailed experimental studies in the Torres Strait which quantify potential impacts to seagrass from the effects of physical disturbances such as shipping accidents or changes to environmental factors associated with climate and predicted climate change, has limited our ability to predict the consequences of disturbances on seagrass habitats and their associated ecosystems and fisheries. This is despite the fact that the potential for impacts from shipping activities is acknowledged as being very high (Queensland Transport and Great Barrier Reef Marine Park Authority 2000) and Torres Strait ecosystems are likely to be particularly vulnerable to the effects of climate change. Seagrasses around the Orman Reefs in particular, were identified as one of the most important areas of seagrass habitat in the Torres Strait and Queensland for dugong (Rasheed et al. 2008; Chartrand et al. 2009; Taylor & Rasheed 2010). Rasheed et al. (2008) determined that the above-ground productivity of Orman Reefs' seagrass meadows were high compared with other tropical seagrass communities and likely to be a key contributor to fisheries production, supporting dugong and turtle populations, and carbon cycling in the central Torres Strait. Understanding the dynamics of these seagrass communities and how they may be impacted by changes to climate and their ability to recover from impact are a critical component for developing effective management strategies for dugong and turtle that depend on these areas for food.

Material and Methods

The Marine Ecology Group (MEG) in collaboration with the Torres Strait Regional Authority (TSRA) Land and Sea Management Unit launched a program to assess critical information for the management of dugong and turtle in the Torres Strait by understanding how their key food resource, seagrass, is affected by seasonal change, climate and their ability to recover from impacts. The project aims to provide key information on how seagrasses in the Torres Strait is affected by climate change and how this may impact on turtle and dugong management.

Manipulative experiments were set up on Mabuiag Island, Torres Strait, in March/April 2011 in one intertidal and one subtidal location (Fig. 1) where the seagrass assemblage was reflective of the 'typical' communities types for the region.

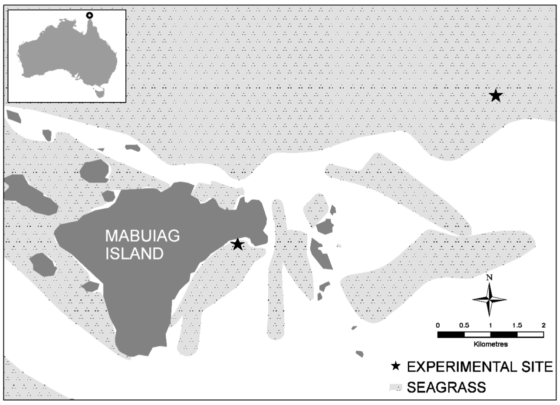

Figure 1: Location of seagrass manipulative experiments, Mabuiag Island, Torres Strait.

Capacity for Seagrass Recovery

The rate of seagrass recovery, the role of sexual and asexual reproduction, and the species involved in re-colonisation following loss/removal was investigated. These investigations followed the methodology developed by Rasheed (1999; 2004) and more recently applied by the MEG at Abbot Point (Unsworth et al. 2010) for investigating seagrass recovery after loss/removal. At each location, three experimental blocks were subject to a randomised design of 12 (0.25 m^2) treatment plots of seagrass. Within each block, the 12 plots were subject to three replicates of four different treatments and were in a randomised block design.

Within each block, six of the 0.25 m^2 plots of seagrass had seagrass material, including roots and rhizomes, removed. To determine how recolonisation was influenced by asexual reproduction (seagrass runners), half (three) of the cleared plots in each block had an aluminium border sunk 500mm into the sediment. The border isolated treatments from asexual colonisation by stopping rhizome extension from seagrass surrounding the plots. To investigate how recolonisation was influenced by the availability of sexual propagules (seeds), recovery of seagrass was compared among plots that had all material removed but the seed bank left intact. Recolonisation of all the cleared plots were compared monthly to control plots in each block that were left undisturbed. Seagrass recovery and re-growth from each individual 0.25 m^2 plot was measured using leaf shoot density and visual estimates of above-ground biomass (Rasheed 1999; 2004).

Seagrass Productivity

The primary productivity of intertidal and subtidal seagrass was measured quarterly using techniques applied by the MEG to determine productivity of seagrass meadows at the Orman Reefs, Torres Strait

(Rasheed et al. 2008) and at Abbot Point (Unsworth et al. 2010). This followed methods outlined in Short and Duarte (2001), and was used to determine the above- and below-ground productivity of each seagrass species found within the meadows. A combination of leaf marking, rhizome tagging and leaf clipping methods were used according to growth habits of seagrass species.

Environmental Parameter monitoring

To develop a relationship between changes in light and temperature and other water quality parameters to seagrass condition and to help model the potential impacts of climate and natural inter-annual changes to seagrasses, water temperature, light (PAR), salinity and pH levels were assessed intertidally and subtidally using in-situ loggers.

Results and Discussion

The three intertidal experimental blocks were located in a dense *Cymodocea serrulata* dominated meadow that comprised a total of seven species of seagrass: *Enhalus acoroides; Thalassia hemprichii; Cymodocea serrulata; Cymodocea rotundata; Halodule uninervis* (wide and narrow leaf morphologies); *Halophia ovalis* and *Syringodium isoetifolium*. The three subtidal blocks were located in a *Syringodium isoetifolium/Halophila spinulosa* dominated meadow at approximately 6.0m dbMSL. Poor weather prevented monthly sampling at the subtidal location; recovery was only able to be measured at 4.5 months post clearing. This meadow consisted of six seagrass species: *Cymodocea serrulata, Cymodocea rotundata, Syringodium isoetifolium, Halophila ovalis, Halophila spinulosa* and *Halophila decipiens.*

Capacity for seagrass recovery

Understanding the capacity of a seagrass meadow to be resilient to future stressors requires knowledge of the ability of the plants to recover after a loss. The role of sexual and asexual reproduction (seeds versus runners) was a major factor in the initial recovery of cleared experimental plots. In general, preventing asexual colonisation (bordering) had a significant impact on the rate at which cleared plots recovered in relation to control plots particularly in the intertidal zone. Five months after clearing, no bordered plots had recovered to control levels in either the intertidal or subtidal zones. In contrast, where asexual colonisation was permitted seagrass biomass had recovered within 5 months for intertidal seagrass and had shown a faster recovery rate than in plots where only sexual colonisation was available in the subtidal (Fig. 2-3).

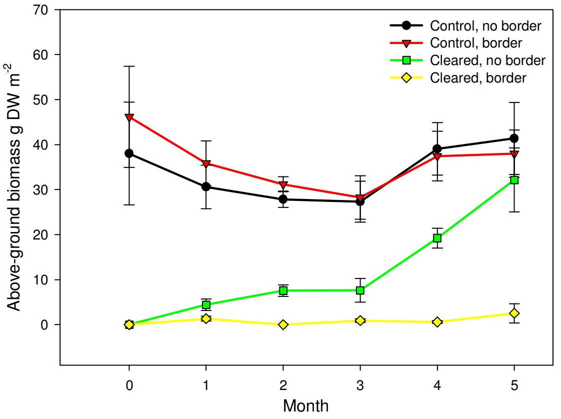

Figure 2: Mean above-ground biomass (g DW m^{-2}) for each treatment in the intertidal region.

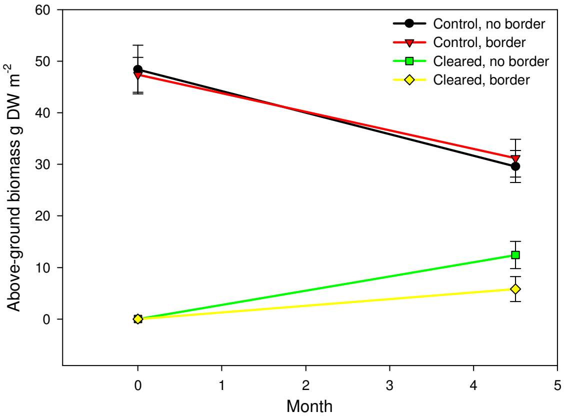

Figure 3: Mean above-ground biomass (g DW m^{-2}) for each treatment in the subtidal region.

Recovery of intertidal seagrass was dominated by pioneering *Halophila ovalis* and *Halodule uninervis* and rhizome extension (in non-bordered plots) of some of the larger species, *Cymodocea serrulata and Syringodium isoetifolium.* Subtidally, recovery at five months post clearing was dominated by *Halophila spinulosa* and *Halophila ovalis.*

The results indicate that the intertidal seagrass meadow dominated by *Cymodocea serrulata* was likely to have a strong reliance on asexual reproduction for recovery from losses, despite regular sighting of flowering and relatively high numbers of seeds recorded (159 ± 28.36 m^{-2}). The high reliance of Mabuiag intertidal meadows on asexual colonisation is similar to other studies conducted within shallow coastal, high density reef meadows on reef platforms and muddy estuaries of far north Queensland (Rasheed 1999; 2004; Unsworth et al 2010).

In contrast to the intertidal, the deepwater *Syringodium isoetifolium/Halophila spinulosa* meadow showed the beginnings of recovery through a combination of asexual and sexual means, indicating a greater capacity for meadow recovery from larger scale disturbances. Unsworth et al. (2010) reported similar findings on a deepwater *Halophila spinulosa* meadow at Abbot Point, Queensland, albeit seagrass had recovered to pre-disturbance levels within 3 months in that case.

Seagrass Productivity

Above-ground and below-ground productivity of the key intertidal species, *Cymodocea serrulata, Cymodocea rotundata, Halodule uninervis* and *Syringodium isoetifolium*, was determined in April and July 2011. Growth rates, meadow turnover time and carbon production were determined.

Environmental Parameter monitoring

Seagrasses in the intertidal zone were exposed during daylight hours on low tide in two periods each month between late March and mid August 2011 for approximately 1.5 hours each occasion (Fig. 4).

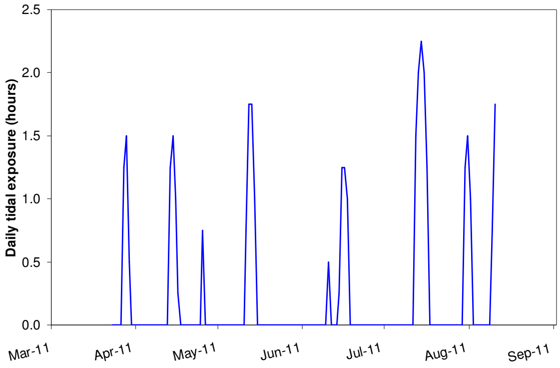

Figure 4: Total daily tidal exposure during daylight hours (0600-1800) at Mabuiag Island, Torres Strait, March-August 2011

These periods of exposure corresponded to peaks in the mean and maximum daily water temperatures recorded in the intertidal (Fig. 5).

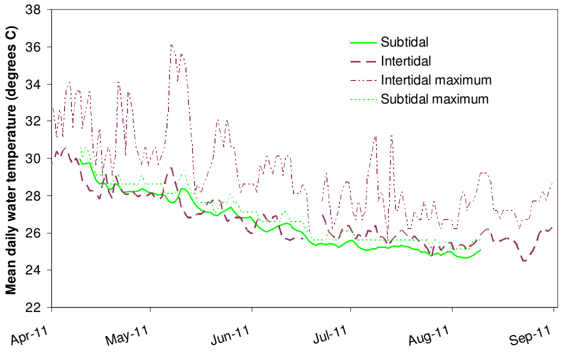

Figure 5: Mean and maximum daily water temperature (C) recorded by *in situ* temperature loggers in the seagrass canopy for intertidal and subtidal meadows at Mabuiag Island, Torres Strait, April-August 2011

The maximum water temperature recorded in the intertidal was 40.5 °C in late March 2011, indicating that the shallow pools of water that are retained over the seagrass meadow become extremely hot during low tide exposure events. The average intertidal water temperature slowly declined from June, as expected with the transition from the hot months of the monsoon season to the cooler dry season. Interestingly, the mean daily water temperature as recorded at the canopy height of seagrasses in the subtidal (6m below mean sea level) was very similar to that of the intertidal region between April and June, minus the sharp peaks observed in the intertidal zone during exposure times (Fig. 5).

Light data collected in the intertidal and subtidal regions demonstrated the high variability exhibited in the amount of light that reaches seagrasses and is available for use in photosynthesis (Fig. 6).

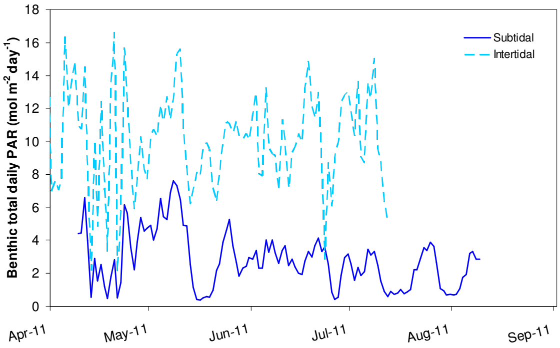

Figure 6: Benthic total daily PAR (mol m^{-2} day^{-1}) recorded by in situ PAR loggers in the seagrass canopy of intertidal and subtidal meadows at Mabuiag Island, Torres Strait, April – August 2011.

PAR levels showed expected responses to weather and tidal patterns. During periods of heavy rainfall, PAR decreased in both the intertidal and subtidal, likely due to a high percentage of cloud cover lowering atmospheric PAR. There appeared to be very little change in the average benthic total PAR between April and August 2011, however more data is needed before any seasonal pattern may be established. Average PAR levels were approximately three times higher in the intertidal than in the subtidal. Variability was also much greater in the intertidal which was likely to have been influenced by tidal regimes coupled with windy conditions. A low tide at midday (for example) would have left the PAR loggers exposed during the time when sunlight was strongest, substantially increasing PAR. Conversely, on a midday high tide the PAR loggers would have been completely submerged and would have reported lower PAR levels. The implications of varying PAR levels on the growth and functioning of seagrasses will be discussed in the final report.

Other environmental parameters that were collected between April and August include pH, salinity and specific conductivity.

The Torres Strait is home to some of the healthiest and pristine seagrasses in Queensland which are locally important to the significant dugong and turtle populations and commercial fisheries species that depend on these habitats. The large areas of dense seagrass meadows located throughout the region are an important source of primary production for the marine ecosystem. The results from the first five months of this study are developing our understanding of the potential impacts to seagrass from climate change and other anthropogenic impacts such as shipping accidents and the implications for the management of dugong, turtle and other fisheries that rely on seagrasses in the Torres Strait.

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References

Brouns JJWM (1985) A comparison of the annual production and biomass in three monospecific stands of seagrass *Thalassia hemprichii* (Ehrenb.) Aschers. Aq Bot 23:149-175.

Campbell SJ, McKenzie LJ (2004) Flood related loss and recovery of intertidal seagrass meadows in southern Queensland, Australia. Estuarine, Coastal and Shelf Science 60:477-490.

Coles RG, McKenzie LJ, Campbell SJ (2003) The seagrasses of Eastern Australia. In: Green, EP, Short, FT, Spalding, MD (eds). The World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley USA.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neil RV, Paruelo J, Raskin RG, Sutton P, van der Belt M (1997). The value of the world's ecosystem services and natural capital. Nat 387:253-260.

Daniell J, Hemer M, Heap A, Mathews E, Sbaffi L, Hughes M, Harris P (2006) Biophysical Processes in the Torres Strait Marine Ecosystem II. Survey results and review of activities in response to CRC objectives. Geoscience Australia, Record 2006/10, 210pp.

Duarte CM, Terrados J, Agawin NSR, Fortes MD, Bach S, Kenworthy WJ (1997) Response of a mixed Philippine seagrass meadow to experimental burial. Mar Ecol Prog Ser 147:285-294.

Erftemeijer PLA, Herman PMJ (1994) Seasonal changes in environmental variables, biomass, production and nutrient contents in two contrasting tropical intertidal seagrass beds in South Sulawesi, Indonesia. Oecologia 99:45-59.

Johannes RE, MacFarlane W (1991) Traditional fishing in Torres Straits Islands. CSIRO Division of Fisheries, Hobart.

Klumpp DW, Salita-Espiosa JS, Fortes MD (1993) Feeding ecology and the trophic role of sea urchins in a tropical seagrass community. Aq Bot 45:205-229.

Kwan D (2002) Towards a sustainable Indigenous fishery for dugongs in Torres Strait: A contribution of empirical data and process. PhD thesis, James Cook University, Townsville.

Lanyon JM, Marsh H (1995) Temporal changes in the abundance of some tropical intertidal seagrasses in North Queensland. Aq Bot 49:217–237.

Long BG, Skewes TD (1996) On the trail of seagrass dieback in Torres Strait. Professional Fisherman (February), 15–18.

Marsh H, Kwan D (2008) Temporal variability in the life history and reproductive biology of female dugongs in Torres Strait: The likely role of sea grass dieback. Cont Sh Res 28:2152 - 2159.

Marsh H, Harris ANW, Lawler IR (1997) The sustainability of the Torres Strait dugong fishery in Torres Strait. Cons Biol 11:1375 -1386.

Marsh H, Eros C, Penrose H, Hughes J (2002) The Dugong, Dugong dugon: Status Reports and Action Plans for Countries and Territories in its Range. UNEP, SSC, IUCN, WCMC and CRC Reef.

Marsh H, Lawler IR, Kwan D, Delean S, Pollock K, Alldredge M (2004) Aerial surveys and the potential biological removal technique indicate that the Torres Strait dugong fishery is unsustainable. An Cons 7:435 - 443.

Mellors JE, Marsh H and Coles RG (1993). Intra-annual changes in seagrass standing crop, Green Island, North Queensland. Aus J Mar and Fresh Res 44:33 - 43.

McKenzie LJ (1994) Seasonal changes in biomass and shoot characteristics of a *Zostera capricorni* Aschers. dominated meadow in Cairns Harbour, northern Queensland. Aus J Mar and Fresh Res 45:1337 -1352.

Nietschmann B (1984) Hunting and ecology of dugongs and green turtles in Torres Strait. Nat Geo Soc Res Rep 17:625 - 651.

Poiner IR, Peterkin C (1996) Seagrasses. In: Zann, LP, Kailola, P (eds), The state of the marine environment report for Australia. Technical Annex: 1. Great Barrier Reef Marine Park Authority, Townsville, Australia: 40 – 45.

Queensland Transport and the Great Barrier Reef Marine Park Authority. (2000). Oil Spill Risk Assessment for the Coastal Waters of Queensland and the Great Barrier Reef Marine Park. Department of Transport (Queensland), 65 pp.

Rasheed MA (1999) Recovery of experimentally created gaps within a tropical *Zostera capricorni* (Aschers.) seagrass meadow, Queensland Australia. J Exp Mar Biol and Ecol 235:183 - 200.

Rasheed MA (2004) Recovery and succession in a multi-species tropical seagrass meadow following experimental disturbance: the role of sexual and asexual reproduction. J Exp Mar Biol and Ecol 310:13 - 45.

Rasheed MA, Dew KR, McKenzie LJ, Coles RG, Kerville S, Campbell SJ (2008) Productivity, carbon assimilation and intra-annual change in tropical reef platform seagrass communities of the Torres Strait, north-eastern Australia. Cont Sh Res 28:2292-2303.

Raven M (1990) The point of no diminishing returns: hunting and resource decline on Boigu Island, Torres Strait. Unpublished PhD Thesis, University of California, Davis.

Rose CD, Dawes CJ (1999) Effects of community structure on the seagrass *Thalassia testudinum*. Mar Ecol Prog Ser 184:83-95.

Sheppard JK, Carter AB, McKenzie LJ, Pritcher CR, Coles RG (2008) Spatial patterns of sub-tidal seagrasses and their tissue nutrients in the Torres Strait, northern Australia: Implications for management. Cont Sh Res 28:2282-2291.

Short FT, Duarte, CM (2001) Methods for the measurement of seagrass growth and production. In: Short F.T. and Coles R.G. (Eds.) Global seagrass research methods. Elsevier Science Publishers, Amsterdam, pp. 155-182.

Taylor HA, Rasheed MA (2010) Badu Island Seagrass Baseline Survey, March 2010. DEEDI Publication (Fisheries Queensland, Northern Fisheries Centre, Cairns), 13pp.

Unsworth RKF, McKenna SA, Rasheed MA (2010). Seasonal dynamics, productivity and resilience of seagrass at the Port of Abbot Point: 2008-2010. DEEDI Publication, Fisheries Queensland, Cairns, 68 pp.

Vanderwal RL (1973) The Torres Strait: Protohistory and beyond. In: Lauer, P (Ed.), Occasional Papers in Anthropology 2. Anthropology Museum, UQ, St Lucia, pp.157-194.