Abstract  The South China Sea coast of Brunei is located near the edge of the Sunda shelf with deep water offshore and very few islands, but numerous submerged bank reefs on the shelf. The inshore coastal waters of this part of northwest Borneo, like much of the shallow Sunda shelf waters of the rest of this large island, are affected by high river runoff and associated plumes of suspended particulates. Consequently nearshore waters are characterized by soft sediments, an inshore turbid zone and very few natural reef coral formations. However, at the fringe of Brunei Bay, human intervention in the form of marine engineering works to create a channel access to Muara port has provided a rock bund substratum that, at one partly wave-sheltered location, has permitted the development of a high cover of a wide range of hard coral colonies. These corals exist in a normal salinity environment (min. 30.3 ppt); apparently the rocky bund protects them from the direct influence of the estuarine plume that emanates from the harbour channel. However, this coral community has colonized, persisted and grown under a high sedimentation regime \( \geq 70 \text{ mg cm}^{-2} \text{ day}^{-1} \), a rate of sedimentation that is comparable to that reported elsewhere for sediment-tolerant Scleractinia but which is considered high for Acropora species. This artificial coral community is of interest in the context of natural reef coral communities near estuaries and, additionally, this particular site has a potentially high bio-monitoring value given present and planned land use changes in the hinterland of Brunei Bay.

Introduction

It is well known that reef corals are, in general, variably intolerant of the highly turbid, low or fluctuating salinity conditions characteristic of the mouths of rivers (West and Van Woestik, 2001, Fabricus 2005). They are often absent near fluvial discharge but, where present, there is typically a gradient in reef communities with declines in coral cover (de Voogd et al. 2009) or both coral cover and species richness (Golbuu et al. 2008) nearer to the source of the discharge. In the Indo-Malayan Archipelago, Borneo, a continental size island straddling the equator, is a region of exceptionally high rainfall, erosion rates and river runoff (Gupta 1996). In consequence, much of the 'Mainland' coastline and inshore waters are characterised by soft sediments and turbid sediment plumes, particularly where coastal waters overlie the shallow Sunda shelf. Reefs near Bornean river mouths are rare, except for the Derawan Island barrier system near the Berau river delta in NE Kalimantan (de Voogd et al. 2009), as are mainland fringing reefs, except for some Sabah coastlines which abut deep waters of the northern South China Sea.

Borneo Bay, receiving freshwater and sediment input from several high turbidity rivers, has no natural coral
substrate at all in the vicinity, yet in recent decades a coral community has developed on a man-made rock bund structure immediately adjacent to the Bay. The location is on Pelumpong Island (Fig. 1) which was formerly connected to the ‘Mainland’ coast of Brunei as a sand spit, nourished by long-shore drift and projecting to the northeast across the southern aspect of inner Brunei Bay. During the development of the deepwater port of Muara in the early 1970s Pelompong became an isolated island due to dredging of a channel to create improved access to the port. The channel or cut was protected from silting by concrete or boulder armouring and by extension of the boulder groynes seaward on both sides of the channel. The placement of these rock structures dates from 1970 to 1973. The new substrate of the S.E.-facing side of the channel groyne on Pelumpong (Fig. 1B, white arrow), protected from the S.W. monsoon and partially protected from the N.E. monsoon, was found in 2006 to be supporting a diverse, healthy coral community. The depth of colonization of the rocks ranges from chart datum to the sandy/silty sea bed at the base of the bund at ca. 4 m depth. Other (detached) revetments along the seaward side of Pelumpong do not harbour corals, presumably because of exposure to wave action and sediment scouring generated by both northeast and southwest monsoons. The objectives of this study were to assess coral cover and species richness at this artificial, near-estuarine site in relation to environmental parameters, particularly salinity and sedimentation.

Materials and Methods

Surveys of corals and environmental conditions at the Pelumpong site were initiated by the second author as part of a mushroom coral survey in Brunei waters, conducted from August 2007 to April 2008, and then subsequently expanded by the first author for other coral taxa in March/April 2010. Corals were growing on the rock bund and on scattered boulders near the base of the bund. The entire colonised rocky area - less than 1 hectare in extent - was surveyed for coral cover using a series of 30 m survey tapes laid parallel to the bund at (a) just below the LWST level (b) 2 m depth and (c) at successive 2 m intervals away from the bund wherever there were boulders. Transect cover values were determined from scores of live coral presence/absence at 25 cm sample intervals along the tapes. Photos of corals sampled in 2007/2008 and 2010 were taken in situ and picture codes matched to skeletal samples taken for verification of identification. Identification of bleach-treated coral samples was largely based on Veron (2000) and the associated CD-ROM software, CORAL-ID. Temperature and salinity profiles (1 m depth increments) were recorded over the August to April
(2007/2008) period at approximately monthly intervals with a YSI 30 SCT meter, and sedimentation rates at the site were determined using sequential deployments of sediment traps (9 traps in clusters of 3 for each array), generally following the methodology of English et al. (1997), except that the trap cylinder diameter was smaller at 2.8 cm and baffles or grids were not used. The trap height-width aspect ratio was 4.2. Trapping extended from 8th September 2007 to 8th March 2008, with irregular, consecutive deployments of duration 11, 113, 72, and 16 days. Trap sediment samples were gravity filtered through pre-weighed filter papers, washed several times with distilled water to remove salts, oven dried at 80°C to constant weight and then cooled and weighed to 2 decimal places. In a preliminary attempt to investigate growth rates and the growth history of massive corals at this site, hand cores (diameter 2.1 cm) were extracted from the growth-axis of a *Porites lutea* colony and, after cutting in half longitudinally with a disc grinder, were examined under UV for fluorescent banding (Fig. 2D).

**Results and Discussion**

The number of scleractinian taxa recorded at Pelumpong is surprisingly high at 34 (Table 1). Moreover, this is certainly an underestimate of the richness at this site since several problematic *Acropora* samples have yet to be identified. Possible nearby sources of larval recruits include the fringing reef around Pelong Rocks and a bank reef, Abana Reef, respectively 6.5 and 8 km offshore from Inner Brunei Bay, or the more distant Barat Banks and Kuraman reefs and shoals toward Labuan. Bottom salinity values at the Pelumpong site, surprisingly, did not drop below 30.3 ppt (Fig. 3) throughout the survey from August 2007 to April 2008, a period that included the wetter N.E. monsoon season. However, mean sedimentation rates at this inshore ‘Mainland’ site exceeded 70 mg cm\(^{-2}\) day\(^{-1}\) with little variance (Fig. 4). Coral cover was high at 59.8% (±6.9 SD, n=6) and some of the coral colonies were well established and large, indicating significant growth rates and/or a long growth history after colonization within the last 37 to 40 years. Yellow-green fluorescent bands in a Pelumpong *Porites lutea* core were evident (Fig. 2D), possibly indicating humic/fulvic acid incorporation into the skeleton during periods of high river run off (Isdale 1984, Isdale et al. 1988, Boto and Isdale 1985). The major bands, approximately one cm apart (Fig. 2D), may represent peak annual monsoonal sediment plumes.
(northeast monsoon), as in other coastal locations (Tanzil et al. 2009), and, in consequence, growth rates typical for the genus, but the interpretation is complicated by multiple minor bands that are probably linked to other major run-off events. Density banding is known to occur in poritids near to the equator but x-ray facilities were not available for this study, and in any case patterns in near-equatorial poritids elsewhere are variously reported to be complicated by multiple dense - less dense alternations within an annual growth increment (Scoffin et al. 1992), or are less pronounced (True 2004).

Some taxa, e.g. *Pectinia paeonia* (Veron 2000) and *Turbinaria mesenterina* (Sofonia and Anthony 2008), are known to be tolerant of moderate to high amounts of sedimentation but others, notably the *Acropora* species, are generally not. The inferred sedimentation rates tolerated by living corals at Pelumpong are as high as, or higher than, many rates reported elsewhere in the literature (Dodge and Vaissny 1977, Lane 1991, Dikou and Woesik 2006). It should be pointed out however that in energetic shallow reef environments, sediment traps may at worst provide misleading information on suspended sediment particle behaviour or at best may only approximate sediment deposition rates (Storlazzi et al. 2011).

Inferred sedimentation rates (more strictly – trap accumulation rates) may exceed actual deposition rates to coral substrata. In fact it is postulated that, at the Pelumpong site, moderate wave exposure provides a passive mechanism aiding re-suspension and sediment removal from colony surfaces as a supplement to energy-expensive, active sediment rejection mechanisms.

The fortuitous placement of rock substrata has allowed the development of a healthy coral community at this Pelumpong site, a location that has a suitable salinity regime yet, seemingly, a challenging sedimentation environment. The existence of this community has implications for the assessment of natural reef coral communities in other near-estuarine (unpolluted) environments. In essence, the avail-ability of hard substrata appears to be a major deter-mining factor controlling the presence/absence of attached Scleractinia in turbid near-shore or near-estuarine locations. Colony or reef absence near river outflows may simply reflect the lack of suitable initial foundation material and should not necessarily be interpreted as indicating environmentally no-go areas for colony or reef establishment.
Enhanced erosion, runoff and sedimentation due to deforestation, together with sediment re-suspension caused by land reclamation and coastal development, are major threats facing coastal reefs globally (Burke et al. 2011). A further factor exacerbating the siltation of many reefs, most notably in Southeast Asia, is the wholesale conversion of mangrove (Valiela et al. 2001) and consequent loss or reduction of the sediment trapping role of these biomes. The coastal vegetation of inner Brunei Bay is dominated by mangrove, much of it pristine, yet there are considerable land use changes occurring in the hinterland, with the potential for increased erosion rates. The small, recently established Pelompong coral community at the edge of inner Brunei Bay includes fast growing, sediment-tolerant species that are robust and resilient to marginal environmental conditions, as has been shown elsewhere (Browne 2012), together with other species (e.g. acroporids) generally considered sediment intolerant. This site has a potentially high biomonitoring value under projected climate change scenarios potentially impacting coastal water quality (IPCC 2007), and, in a local context, in relation to potentially enhanced sediment plumes regimes, given ongoing and planned land use changes around the Bay.

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