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Baseline

Corals persisting in naturally turbid waters adjacent to a pristine catchment in Solomon Islands

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ABSTRACT

Few water quality measurements exist from pristine environments, with fewer reported studies of coastal water quality from Solomon Islands. Water quality benchmarks for the Solomons have relied on data from other geographic regions, often from quite different higher latitude developed nations, with large land masses. We present the first data of inshore turbidity and sedimentation rate for a pristine catchment on Isabel Island. Surveys recorded relatively high coral cover. The lowest cover was recorded at 22.7% (Jejevo) despite this site having a mean turbidity (continuous monitoring) of 32 NTU. However, a similar site (Jihro) was significantly less turbid (2.1 mean NTU) over the same period. This difference in turbidity is likely due to natural features of the Jihro River promoting sedimentation before reaching coastal sites. We provide an important baseline for Solomon Island inshore systems, whilst demonstrating the importance of continuous monitoring to capture episodic high turbidity events.

Globally, coastal coral reefs are being exposed to increasing loads of land based nutrients, sediments and pollutants (Fabricius et al., 2013), with a recent report suggesting a quarter of the earth's reefs are currently threatened by run-off (Burke et al., 2011). Rivers are the main route by which runoff is transported to inshore reef environments, and during flood events river plumes may even reach offshore reefs (Brodie et al., 2012; Devlin et al., 2000). Turbid river waters with high sediment loads have the potential to cause numerous negative impacts on coral reefs, including: the reduction of available light for coral photosynthesis; smothering, burying or abrasive damage to corals by sediments; reduced salinity due to large freshwater inputs; increased nitrogen and phosphorus concentrations, and the potential to deliver pollutants such as heavy metals, fertilizers, pesticides/herbicides, and hydrocarbons (Erftemeijer et al., 2012; Fabricius, 2005). These impacts rarely occur in isolation and their individual effects on coral health or coral mortality are, therefore, difficult to accurately quantify. Coral reefs within high turbidity environments typically have a reduced depth distribution due to increased light attenuation with studies showing that coral reefs in turbid waters are generally restricted to a depth of <10 m (Yentsch et al., 2002). Turbid waters may also result in changes to coral growth rates, increased mucus production, and increased respiration rates (Dodge and Vaisnys, 1977; Erftemeijer et al., 2012; Fabricius, 2005; Rogers, 1990). High sedimentation and turbidity may also reduce coral reproductive output, larval recruitment success and increase the incidence/virility of coral disease (Erftemeijer et al., 2012; Fabricius, 2005). Coral reefs in turbid environments typically exhibit reduced species richness (Fabricius et al., 2005; Fabricius, 2005; van Woesik et al., 1999) and are dominated by corals better adapted to low light and the removal (or sloughing) of sediment (Anthony, 2000). Nonetheless, several studies have demonstrated that these coral communities are able to survive turbid environments for long periods (Done et al., 2007; Kleypas, 1996; Smithers and Larcombe, 2003).

Several principle parameters are often used as indicators for water quality within inshore areas, including turbidity, suspended sediment concentration, sediment load and sedimentation rate. Past research has focussed on the effect of increased turbidity and sedimentation rate often in response to an environmental or anthropogenic perturbation. For example, road construction in Guam from 1988 to 1990 resulted in large increases in sediment load within run-off, causing high coral mortality and macroalgal overgrowth (Richmond, 1993). Hunter and Evans (1995) surmised the lack of coral in some southern sites of Kaneohe Bay, Hawaii, was the result of high turbidity and associated sedimentation rates from the combined impacts of urban run-off, river channelization, increased sediment load from road construction and decades of dredging. Nugues and Roberts (2003a) noted that sedimentation was responsible for 70–72% of total coral mortality measured at one inshore river site in St Lucia, and that partial mortality was

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highest near river mouths where sedimentation was greatest (Nugues and Roberts, 2003b).

Management of sediment is important to ensure the continued health of coral reefs given the potential impacts of river discharges. Principally, water quality management activities incorporate several key features: the use of appropriate baseline data to understand normal levels for the parameters being monitored, establishment of recommended ranges or maximum levels for parameters using baseline data, and the continued monitoring of parameters to identify when recommended guidelines are exceeded. The establishment of guidelines or limits for water quality provide a valuable benchmark for the assessment of water quality, as well as a reference point for initiating a management response when these limits are exceeded. For instance, within the Great Barrier Reef Marine Park (GBRMP), Australia, a number of state and federal guidelines exist to assist in water quality management. These include trigger values for concentrations of sediment, phytoplankton (chlorophyll *a*), turbidity, pesticides and herbicides. For example, upper guideline values within inshore coral reefs for turbidity are 20 NTU (ANZECC/ARMCANZ, 2000), 5–15 mg L^{-1} for total suspended solids (GBRMPA, 2010), and daily mean sedimentation rates of 3 mg cm^2 day^{-1} annually or 15 mg cm^2 day^{-1} as a daily maximum (GBRMPA, 2010). Given that many of these management principles are reliant on baseline data as a basis for subsequent management actions, water quality management in the absence of appropriate region specific data is challenging. In addition, baseline values and upper limits for water quality from one geographic region are often not appropriate for use in other areas (Moss et al., 2005). Logically this is particularly true for comparisons between regions with very different environmental, socioeconomic, industrial and agricultural practices. However, obtaining water quality measurements for areas lacking baseline data can be difficult due to the potential remoteness of the test environment, lack of scientific resources in the region, expense of monitoring equipment and the difficulty in conducting repetitive monitoring. In this study we assess the inshore coastal water quality and coral communities within a largely pristine region of Isabel Island, Solomon Islands, focussing on the near-shore coastal lagoons adjacent to two riverine catchments. We evaluate point and continuous turbidity sampling methods and their appropriateness for determining baseline water quality measurements. We provide important data for inshore water quality in this remote area, which can be incorporated into the future management of the region. Challenges associated with the collection of reliable, continuous data in these remote environments are also discussed.

Isabel Island is located within the Solomon Island archipelago north of the capital of Honiara. The study area is on the south-western side of Isabel Island which contains fringing reefs, outer barrier reefs and inner lagoonal back reefs (Fig. 1). The area is typically dominated by coral communities, however mangrove and seagrass habitats are also present within the site. Within the study site we investigate two major catchments; the Jejevo catchment which contains the Jejevo River and the Jihro catchment which contains three rivers the Jihro, Nuha and Sivoko (Fig. 1). These two catchments are steep and primarily covered in native forest, with very limited clearing for subsistence gardens. Supplemental sampling was also conducted in the adjacent Heple River. Preliminary observations indicated that turbidity was higher at the Jejevo inshore site. We hypothesised that the difference in turbidity between sites was due to the presence of two shallow coastal lakes at the Jihro site that act as natural settlement ponds: one immediately upstream of the Jihro river mouth; and one on the Sivoko River approximately 1.5 km upstream of the river mouth. Both lakes have very narrow, shallow downstream exit points (Fig. 1). The uppermost settlement pond, Lake Sivoko, had a surface area of 0.16 km^2, average depth of 1.2 m and average width of approximately 190 m whilst the inflow channel on the Sivoko River is approximately 15 m wide. The pond located at the Jihro River mouth had a surface area of 0.25 km^2, average depth of 1.5 m and width of 350 m, the two inflow channels were 20 and 11 m wide for the Nuha and Jihro rivers, respectively. Two primary inshore monitoring sites were selected near the Jejevo (S1) and Jihro (S17) river mouths (Fig. 1) to assess inshore water quality and coral reef condition. Primary monitoring sites were situated at a water depth of 3 m and on sediments directly adjacent to inshore coral reefs (S1 – E159°6′36.608", S8°7′4.874"; S17 – E159°10′24.553″, S8°9′20.969″). Additional sites were also selected on the outer reef edge approximately 2.5 km further offshore (S13 – Jejevo offshore site E159°5′46.745″, S8°7′32.376″; S28 – Jihro offshore site E159°9′30.416″, S8°9′18.853″) (Fig. 1). Details of the measurements taken at these sites and point sampling sites are described below.

Long-term turbidity measurements were made of both the Jejevo and Jihro Rivers upstream of the primary sample sites (1.8 and 1.9 km upstream for the Jejevo and Jihro sites) to assess upstream turbidity using a YSI 6820 V2 Sonde, YSI Australia. Turbidity was also measured at a third site 4 km upstream within the Heple River. The Heple River mouth is situated approximately 16 km South East of the Jejevo River mouth (Fig. 1). Marine water quality sampling at primary Jejevo and Jihro inshore sites (S1 and S17) incorporated the continuous measurement of turbidity, light attenuation and sedimentation rate. Continuous fixed sampling devices were deployed at primary sites from 25 March until 10 May 2013 at a depth of 2 m. Fixed logging instruments were mounted onto a custom built aluminium frame which housed the following equipment: Aquistar Turbidity logger (INW, USA), two light loggers (Odyssey PAR Sensors, Dataflow Systems PTY Ltd, New Zealand) with automated wipers (Hydro wipers, Zebratech, New Zealand). In addition, offshore continuous sampling sites were selected for both Jejevo and Jihro (S13 and S28) as well as a number of other sites within the study area (S3, S27, S18, S19, S52; see Fig. 1) to provide additional spatial data to better evaluate the effect of end-of-river discharge on the Isabel Island lagoon and its potential influence on outer reef coral communities. At these sites the same sampling device arrays were deployed as at primary sites with the exclusion of turbidity sensors. Turbidity and light loggers were set to take measurements at 15 min intervals. Light loggers were positioned 90 cm apart to obtain water column light attenuation, thus providing a measure of water clarity. Three PVC settling tubes (∅50 mm × 350 mm) were attached (60 cm apart) to the aluminium frame at each site to assess sediment settlement rates in the manner of English et al. (1997). Upon retrieval of settling tubes in May, the collected sediment was dried at 60 °C until no further weight change was recorded and the cumulative sedimentation rate determined. To obtain further spatial data, site-wide point measurements of turbidity occurred during three sampling trips on 25 March, 10 May 2013 and 21 November. Point sampling consisted of surface to bottom profiles using a conductivity, temperature and depth logger (RBR-620 CTD, RBR Ltd) combined with a photosynthetic active radiation (PAR) sensor (LI-192 Underwater Quantum Sensor, LI-COR Biosciences, USA), and turbidity sensor (Seapoint turbidity meter, Seapoint Sensors Inc., USA). Point sampling was conducted at both primary and offshore sites and at an additional 30 sites within both the inshore and offshore areas. Hourly wind speed and direction for the area was obtained from a meteorological station situated at Nuha, 8 km southeast of Jejevo River mouth and 2 km northwest of Jihro River.

To better characterise sedimentation rates within the study region five sites were selected for sediment dating. Sediment cores were collected by hand using a ∅90 mm × 1500 mm acrylic tube to a depth of 60–120 cm at the primary inshore site at Jejevo (S1), the inshore site at the Heple River mouth (S8) and an inshore