



Sediment transport trends from a tropical Pacific lagoon as indicated by *Homotrema rubra* taphonomy: Wallis Island, Polynesia



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ABSTRACT

The assessment of sediment transport pathways in carbonate settings is complicated by ecologically sourced sediment. Tracers such as foraminifera have previously been used in these settings to describe the movement of coastal sediments on spatial and temporal scales where traditional grain size methods have limited use. The present study builds on the foraminifera-based tracer method by using *Homotrema rubra*, a foraminifer with an attached life habit (i.e., defined provenance in the reef) to document modern sediment transport trends at Wallis Island, a tropical Pacific lagoon. At Wallis Island, *Homotrema* taphonomic results discriminated amongst modern reef, lagoon, and island (beach) samples. Reef samples contained high concentrations of fragments that were large (>250 μm) and exceptionally- to well-preserved (e.g., intact chambers, red color, angularity). In general, concentrations and degree of taphonomic alteration decreased with distance landward from the reef; lagoon samples were characterized by lower concentrations of *Homotrema* that were smaller in size and less preserved (e.g., pink in color, no chamber structure, rounding of edges). At the greatest distance from the reef, island (beach) samples contained the lowest concentrations of *Homotrema* fragments that were small, well rounded and bleached. In this regard, *Homotrema* taphonomy is a useful indicator of the direction and forcing of sediment transport and will therefore be useful in detecting overwash deposits in tropical settings, where distinguishing event deposits from surrounding sediment is problematic.

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1. Introduction

Sedimentological criteria such as grain size distributions and changes in statistics (e.g., mean, mode, sorting) are widely used to assess the direction, magnitude, and volume of sediment movement in a variety of coastal environments (e.g., Gao and Collins, 1994; van Lancker et al., 2004; Pilarczyk et al., 2011; Wang et al., 2011) and are increasingly used to discriminate storm and tsunami deposits from surrounding sediment (e.g., Donnelly and Woodruff, 2007; Morton et al., 2007; Woodruff et al., 2008; Donato et al., 2009). In carbonate settings, sediment is ecologically sourced, limiting the applicability of traditional grain size analysis in determining sediment transport pathways (e.g., Kench, 1998). Rather, 'tracers' such as unattached benthic foraminifera have been used to gain insight into sediment movement due to their fidelity to specific ecological environments (e.g., Li et al., 1998; Yamano

et al., 2002; Hohenegger, 2006; Yordanova and Hohenegger, 2007; Schröder-Adams et al., 2008; Gischler, 2011; Dawson et al., 2012).

Benthic foraminifera with an attached life habit (e.g., *Homotrema rubra*) offer a defined provenance and are potentially more useful in constraining and quantifying source, accumulation, and direction of sediment transport (MacKenzie et al., 1965; Machado and Moraes, 2002). *H. rubra* (Lamarck) is a sessile benthic foraminifera that encrusts on corals and other reef detritus in semi-tropical to tropical reef settings (Emiliani, 1951; Machado and Moraes, 2002). Living individuals maintain a vibrant reddish color that bleaches to whitish-pink following detachment from the reef by large waves and currents (MacKenzie et al., 1965). *Homotrema* is a major component of coastal sediments from the Caribbean (e.g., the Bahamas; Dix et al., 1999; Bermuda; Javaux and Scott, 2003) and has also been documented in nearshore sediments from South America (e.g., Brazil; Machado and Moraes, 2002; Mexico; Gischler and Möder, 2009), Australia (e.g., Great Barrier Reef; Dawson et al., 2012), Japan (Hohenegger, 2006), the Red Sea (Parker et al., 2012) and islands of the Indian Ocean (e.g., Maldives; Parker and Gischler, 2011; Indonesia; Hohenegger, 2006) and South Pacific (e.g.,

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New Caledonia; Debenay and Payri, 2010; French Polynesia; Bicchi et al., 2002). *Homotrema* is common in both restricted microhabitats (e.g., reef crevices, walls of submarine caves, undersides of corals and mollusks) and exposed reef surfaces (Elliott et al., 1996; Gischler and Ginsburg, 1996). Environmental conditions (e.g., wave climate, depth, and substrate) along with ontogeny control the distribution and life habit of the foraminifer; knobby and globose tests are typical of lower energy cryptic spaces, whereas hemispherical and encrusting forms commonly grow on exposed reef areas (Elliott et al., 1996).

Homotrema fragments have previously been used to assess the direction of sediment transport in carbonate lagoons. For example, MacKenzie et al. (1965) reported that the concentration of *Homotrema* fragments in nearshore sediments decreased markedly along a transect from the reef to the coastline, with lagoons and other lower energy areas containing the lowest concentrations versus energetic environments near the reef containing the highest. It was also found that the degree of taphonomic alteration of *Homotrema* fragments (e.g., size, color and angularity) is a function of distance from the reef; beaches contained fragments that were small and well-rounded; whereas sediments on the reef contained predominantly large fragments that were red. These findings are consistent with Machado and Moraes (2002) who found that well-preserved, reddish fragments that had angular edges were an indicator of proximity to the reef source; whereas fragments that were rounded and slightly bleached were indicative of sediments that had been transported.

Pilarczyk and Reinhardt (2012) used the concentration and taphonomic character of *Homotrema* fragments (e.g., color, angularity, chamber structure and size) to document an overwash deposit in coastal ponds on Anegea, British Virgin Islands, and showed that this method has potential in discriminating between storm and tsunami deposition in Caribbean reef settings because it provides directionality of sediment transport. The application of *Homotrema* as a sediment transport and overwash indicator in areas outside of the semi- to tropical Americas, where concentrations are reportedly much lower, has never been assessed. In this study, the utility of the attached foraminifer *H. rubra* is tested as a sediment transport and overwash indicator in a Pacific lagoon (Fig. 1). Sediment transport studies of this nature will be important in assessing and mitigating the risk of storms and tsunamis in carbonate coastlines worldwide (e.g., Goff et al., 2008, 2011b); particularly at locations such as Polynesian islands where the record of past events is fragmentary (Lamarche et al., 2010) and little is known about events prior to the early 1800s (e.g., Goff et al., 2011a).

2. Site description

Wallis (Uvea) is a small (~95 km²), low-lying (maximum 115 m asl.) volcanic Polynesian island (176°10'W, 13°18'S) located ~380 km from Samoa and ~740 km from Fiji (Fig. 1A). A living barrier reef surrounds the island on all sides with narrow entrance channels located on its southern and western flanks (Fig. 1B). The barrier reef at Wallis is partly exposed at low tide and consists of a steeply sloping forereef at its seaward margin, a marked ridge at the reef crest and a gently sloping reef apron. Deep holes punctuate the reef in several areas (see 'Eastern profile' on Fig. 1B). The lagoon, with a flat platform interior consisting of consolidated coral sand, fringes the island and varies in width from <1.0 km at the south-east to ~3.0 km north of Mata'utu on the east side of the island. The platform interior is generally exposed at low tide and hosts a low number of small patch reefs. These patch reefs, along with reef rubble, dead corals and mollusk fragments, support minor populations of living *Homotrema*. Between the fringing and barrier reefs, a shallow lagoon (maximum depth of 60 m) is home to abundant live corals and marks the main navigation channel around the island (Stearns, 1945). Several small islands line the barrier reef to the north, south and east of the island. The wave climate varies around the lagoon, with the southern region experiencing the highest wave intensities. Coastlines of the Wallis archipelago are dominated by sandy

beaches interspersed with mangrove patches. The beach sand is mainly composed of foraminifera and coarse fragments of mollusks and corals. The maximum tidal amplitude for Wallis is 1.55 m (Egbert and Erofeeva, 2002).

The absence of rivers on Wallis has resulted in limited terrestrial sediment input into the lagoon. Rather, barrier and patch reefs appear to be the dominant sediment sources, although patterns of sediment transport and residence time in the lagoon are undocumented. Marine inundation poses a significant threat to Wallis Island. The island's position within the Pacific Ocean makes it susceptible to earthquake-generated tsunamis (e.g., 2009 South Pacific tsunami; Lamarche et al., 2010) as well as volcano-generated tsunamis (e.g., Kuwae caldera collapse in A.D. 1452; Goff et al., 2011b). In addition, notable cyclones in 1973, 1984, and 2002 have severely impacted the island (Diamond et al., 2011). To date, little historical information and no geologic evidence of overwash has been documented on Wallis, precluding the ability to properly assess the risk of both cyclones and tsunamis.

3. Methods

3.1. Sample collection

In August 2011, 52 surface sediment samples were collected from the eastern (n = 20), western (n = 11), northern (n = 5) and southern (n = 16) basins of the Wallis Island lagoon. Samples were obtained from exposed beach sediments (depths <1 m) and during boat surveys (depths >1 m). Subtidal samples were collected by free-diving and depths were obtained using a SUUNTO depth gauge. All sub-environments within the lagoon were sampled (i.e., outer reef, reef crest, reef apron, lagoon, deep hole and island beaches). Nodes at the reef crest were used to calculate the distance of each sample location relative to the main source of living *Homotrema*.

3.2. *Homotrema* taphonomic analysis

Surface sediment samples (5–10 cm³) were wet sieved at 63 µm and dried at 25 °C for taphonomic analysis. A dry splitter was used to subdivide samples so that counts of ~300 *Homotrema* individuals could be made using a binocular dissecting microscope. Scanning Electron Microscope (SEM) images of diagnostic specimens were taken using a Nikon Neoscope desktop SEM (Plate 1). The total concentration of *Homotrema* individuals per unit volume of sediment was enumerated and plotted against increasing distance from the reef. In addition, the degree of taphonomic preservation (exceptionally-preserved, well-preserved, moderately-preserved or highly-altered) and test size (>500 µm, 250–500 µm, 150–250 µm, or <150 µm) were recorded following the methods of Pilarczyk and Reinhardt (2012). Red colored tests with angular edges and an intact chamber structure (i.e., areolae present) were recorded as 'exceptionally-preserved', while 'well-preserved' tests were pink, angular and had hollowed chambers (i.e., areolae absent). 'Moderately-preserved' individuals were pink and had rounded edges and hollowed chambers (i.e., areolae absent), whereas 'highly-altered' individuals were whitish-pink in color and well rounded (Table 1). Individuals that were bleached white were indistinguishable from surrounding sediment (e.g., bleached coral and calcareous algae fragments; e.g., Parker, 2009) and were omitted from analysis. Similar to *Homotrema*, *Miniacina* and *Sporadotrema* are large foraminifera with colored tests (ranging from red to orange to yellow) that grow attached to tropical coral reefs (e.g., Parker and Gischler, 2011). These genera were identified in lagoon sediments at Wallis, but were omitted from analysis, because the degree to which their fragments bleach following detachment from the reef has not been documented. Q-mode (statistically similar populations) cluster analysis of the *Homotrema* taphonomic data (i.e., degree of preservation and fragment size [500 µm, 250–500 µm, 150–250 µm, or <150 µm]) was performed in the program PAST (Hammer et al., 2001) using Ward's Minimum variance (e.g.,

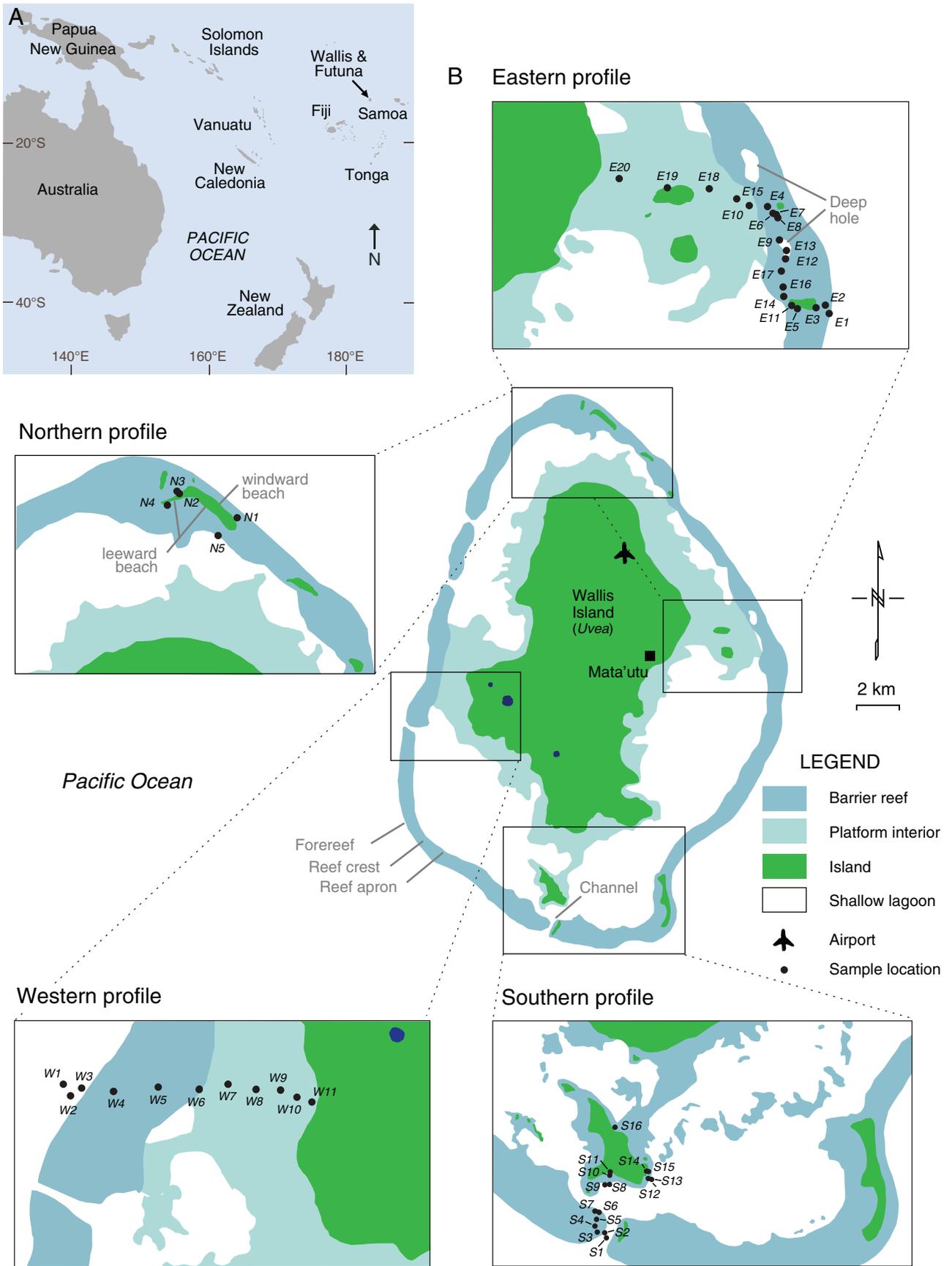


Fig. 1. (A) Location map of Wallis Island within the Pacific Ocean. (B) Map of Wallis Island showing sample locations along four surface profiles (eastern, western, northern, southern). Major geomorphological features are indicated.

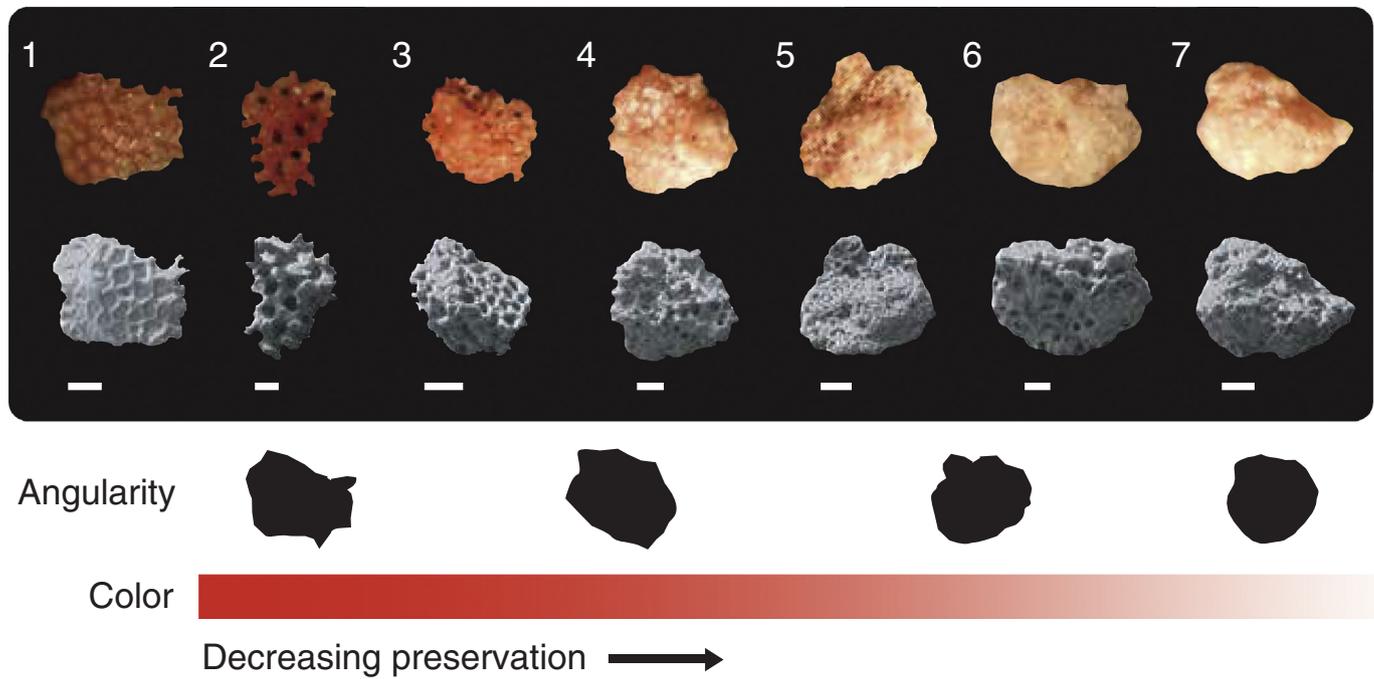


Plate 1. *Homotrema* individuals taphonomically degrade in color and angularity resulting from increased exposure time after death. 1 – Exceptionally-preserved specimen with a red color, well defined test (i.e., areolae present) and angular edges. 2–3 Well-preserved individuals with pink tests, hollowed chambers (i.e., areolae absent) and angular edges. 4–5 Moderately-preserved *Homotrema* that are pink, rounded and have hollowed chambers (i.e., areolae absent). 6–7 Highly-altered individuals that are whitish-pink in color and are well rounded. White bars represent 100 μm .

Fishbein and Patterson, 1993) and is reported as squared Euclidean distances (e.g., Davis, 2002). Cluster analysis was used to determine the relationship between *Homotrema* taphonomic assemblages and specific reefal sub-environments.

4. Results

4.1. Eastern lagoon profile

Along the eastern lagoon profile, *Homotrema* concentrations were highest on the reef crest (65 fragments per cm^3) and apron (61 fragments per cm^3) and generally decreased with increasing distance landward from the reef (5 fragments per cm^3 at 3.0 km; Fig. 2). Exceptions include site E13 (deep hole within reef apron; 171 fragments per cm^3) and various locations in the lagoon where concentrations appear to be anomalously high. For example, between 0.6 and 0.9 km from the reef crest, concentrations range from 14 (site E4) to 35 (site E7) fragments per cm^3 . Exceptionally- and well-preserved individuals are only present in sediments that are within 0.9 km from the reef (e.g., E1–E17) and are highest on the reef crest (14 exceptionally-preserved and 36 well-preserved fragments per cm^3 at site E1) and in the deep hole at site E13 (51 exceptionally-preserved and 84 well-preserved per cm^3). Similarly, extra large tests (>500 μm) are restricted to distances <1.4 km from the reef; whereas large tests (250–500 μm) were present in all samples with the highest abundances found in leeward island and lagoon sediments between 0.6 and 0.8 km (E4 to E17).

4.2. Western lagoon profile

Homotrema concentrations in sediments along the western profile were significantly lower than those along the eastern profile. Concentrations decreased markedly with increasing distance from the reef crest; the highest concentrations were found at the outer reef (~30 fragments per cm^3), reef crest (28 fragments per cm^3) and reef apron (~27 fragments per cm^3), and decreased to ~9 fragments per cm^3 in the lagoon (Fig. 3). Sites W9–W11, at a distance of ~2.5 km from the reef crest, showed a slight increase in *Homotrema* concentrations (6–11 fragments per cm^3), but fragments were small and highly-altered. Concentrations of exceptionally- and well-preserved fragments peaked in outer reef sediments (e.g., site W1 contained 15 exceptionally-preserved and 9 well-preserved fragments) and decreased markedly with increasing distance towards land (e.g., site W7 contained 2 exceptionally- and 1 well-preserved fragments). Fragment size showed similar trends with the highest concentrations of extra large individuals peaking along the outer reef (e.g., 15 fragments per cm^3) and decreasing to 0 individuals at a distance of ~2.0 km from the reef.

4.3. Northern lagoon profile

The north side of the island contained the highest concentrations of *Homotrema* fragments; 100 individuals per cm^3 were enumerated in reef sediments from the northern profile whereas similar environments on the eastern (~63 fragments per cm^3), southern (~35 fragments per

Table 1
Preservation (color, angularity and chamber structure) of *Homotrema* fragments.

Degree of taphonomic preservation	Test color	Fragment angularity	Chamber structure
Exceptionally-preserved	Red	Angular	Intact
Well-preserved	Pink	Angular	Hollowed
Moderately-preserved	Pink	Rounded	Hollowed
Highly altered	Light-pink to white	Highly rounded	Hollowed

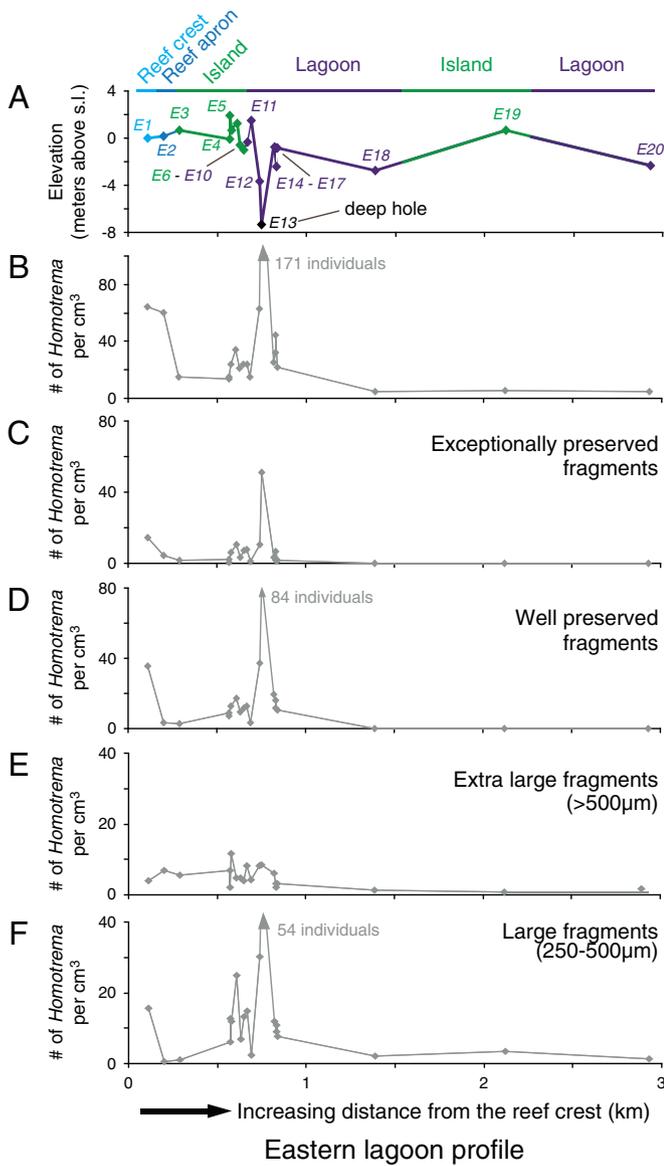


Fig. 2. *Homotrema* taphonomic data along the eastern profile. (A) Elevation along a profile extending from the reef crest to the lagoon (Fig. 1). (B) Number of *Homotrema* individuals in 1 cm³ of surface sediment. Abundance of exceptionally-preserved (C) and well-preserved (D) *Homotrema* fragments (Plate 1). Abundance of extra large (E) and large (F) sized fragments.

cm³) and western (29 fragments per cm³) sides of the island contained significantly lower concentrations. As with all other profiles, well-preserved (e.g., from 31 fragments per cm³ at N1 to 1 at N5) and extra large individuals (e.g., from 38 fragments per cm³ at N1 to 1 at N5) decreased with distance from the reef (Fig. 4).

4.4. Southern lagoon profile

On the south side of Wallis Island, *Homotrema* concentrations were highest in the channel (~35 fragments per cm³), reef apron (~37 fragments) and lagoon (~37 fragments); while much lower in the reef crest (~10 fragments) and island (beach; ~8 fragments) sediments (Fig. 5). The low representation of *Homotrema* fragments in samples S3, S4 and S5 is in contrast to reef crest sediments from other profiles that generally contain high concentrations. Concentrations of exceptionally- and well-preserved fragments showed some trends with distance, but in both cases, reef crest

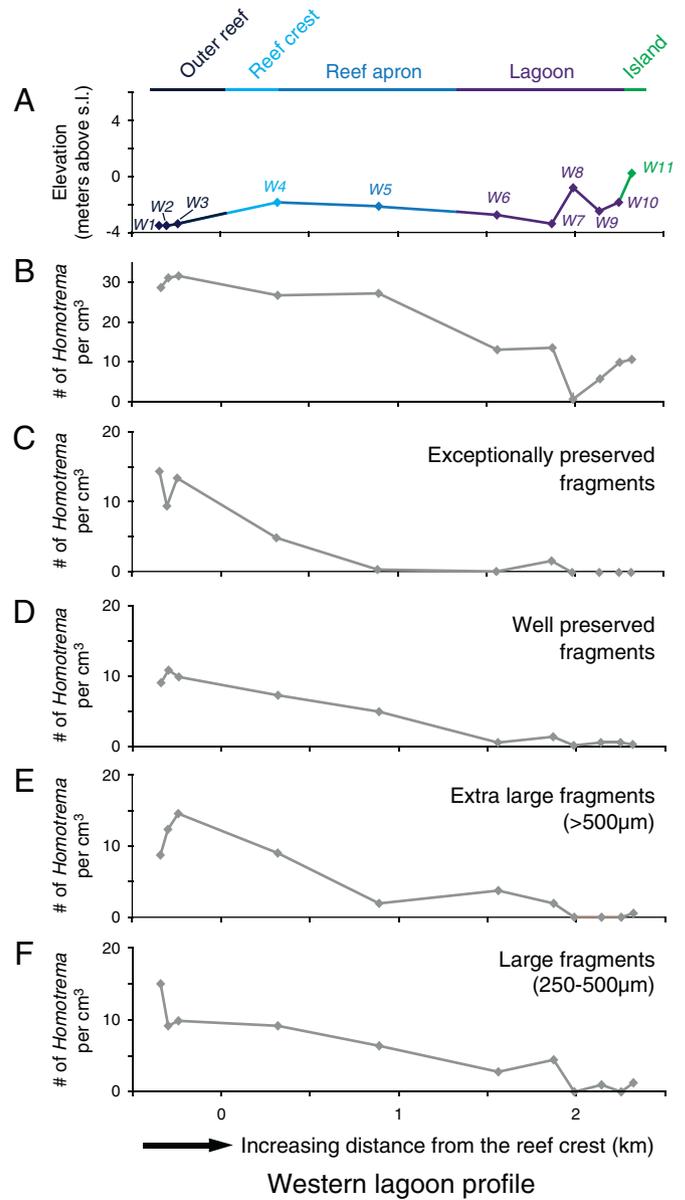


Fig. 3. *Homotrema* taphonomic data along the western profile. (A) Elevation along a profile extending from the outer reef to the main island (Fig. 1). (B) Number of *Homotrema* individuals in 1 cm³ of surface sediment. Abundance of exceptionally-preserved (C) and well-preserved (D) *Homotrema* fragments (Plate 1). Abundance of extra large (E) and large (F) sized fragments.

samples (sites S3–S5) contained markedly low numbers (~2 exceptionally-preserved, ~9 well-preserved) compared to surrounding channel (~9 exceptionally-preserved, ~22 well-preserved) and reef apron (~11 exceptionally-preserved, ~19 well-preserved) sediments. Similarly, concentrations of extra large fragments were highest in the channel (~9 fragments per cm³) and reef apron (~8 fragments per cm³) and decreased in concentration to 0 fragments per cm³ by 2.5 km from the reef crest (e.g., site S16). In contrast, concentrations of large fragments did not vary as closely with distance, although the highest concentrations were generally found in reef proximal sediments (e.g., sites S1 to S8) and lowest concentrations at distances >2.0 km from the reef (e.g., site S16).

4.5. Cluster analysis

Cluster analysis of the *Homotrema* data distinguished five main physiographic zones related to distance from the reef: outer reef,

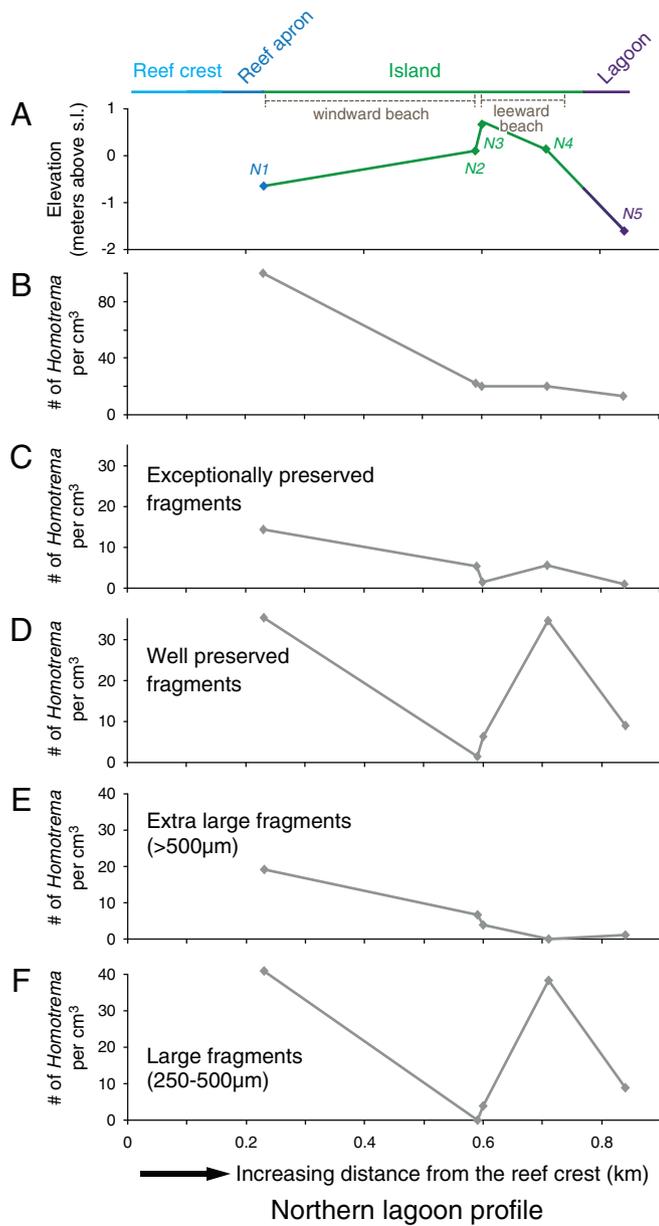


Fig. 4. *Homotrema* taphonomic data along the northern profile. (A) Elevation along a profile extending from the reef apron to the lagoon (Fig. 1). (B) Number of *Homotrema* individuals in 1 cm³ of surface sediment. Abundance of exceptionally-preserved (C) and well-preserved (D) *Homotrema* fragments (Plate 1). Abundance of extra large (E) and large (F) sized fragments.

reef, lagoon, deep hole and island (beach; Fig. 6). Along the Eastern profile, Q-mode cluster analysis discriminated between reef-proximal (0.6 km ± 0.1), intermediate (0.8 km ± 0.1), and distal (2.2 km ± 0.8) lagoon samples. The deep hole sample on the eastern side of the island (site E13) clustered separately owing to the anomalously high concentrations of exceptionally-preserved individuals at this non-reef location. Outer reef and reef locations were discriminated in samples from the western side of Wallis Island where the highest concentrations of *Homotrema* fragments were found on the outer reef. Along the southern profile, reef and lagoon samples clustered separately but reef sites (S3–S5) were removed from the cluster analysis since they had anomalously low concentrations of *Homotrema* and consequently clustered erroneously with lagoon samples. In addition to discriminating between reef and island (beach) samples along the northern profile, windward and leeward beaches clustered separately.

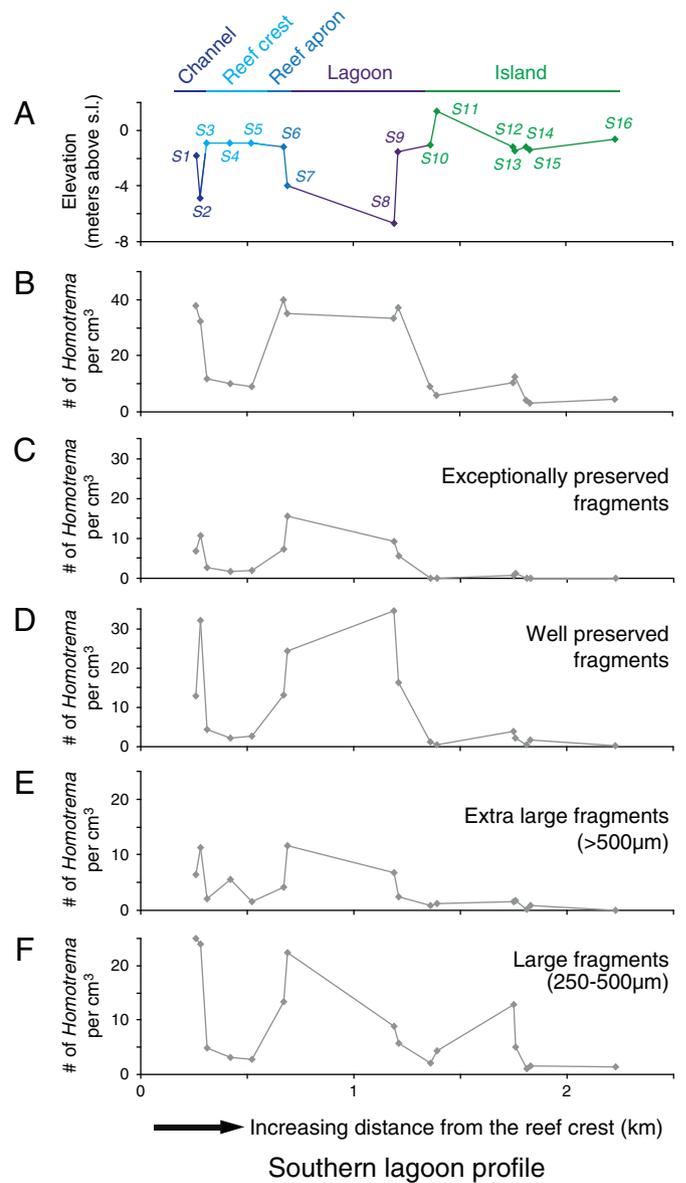


Fig. 5. *Homotrema* taphonomic data along the southern profile. (A) Elevation along a profile extending from the entrance channel to the main island (Fig. 1). (B) Number of *Homotrema* individuals in 1 cm³ of surface sediment. Abundance of exceptionally-preserved (C) and well-preserved (D) *Homotrema* fragments (Plate 1). Abundance of extra large (E) and large (F) sized fragments.

5. Discussion

5.1. *Homotrema* as a sediment transport indicator

Coastal sediments from Wallis Island contain *Homotrema* fragments that vary in taphonomic condition based on their proximity to the reef; providing insight into patterns of relative transport capacity for the Wallis coastal zone. In all profiles, concentrations of the foraminifer were generally highest at the reef (e.g., 100, 65, 38 and 32 fragments per cm³ in the northern, eastern, southern and western profiles, respectively) and decreased markedly over distances ranging from 0.0 to 3.0 km (Figs. 2–5). For example, on the eastern profile, 65 fragments per cm³ on the reef (0.0 km) decreased to 22 per cm³ at ~0.8 km and to 5 per cm³ at 2.9 km; while concentrations on the northern flank (100 per cm³; 0.2 km) decreased to 22 individuals per cm³ at 0.6 km and finally to 13 per cm³ at 0.8 km. The difference in concentrations between the four profiles appears to be related to varying wave climates

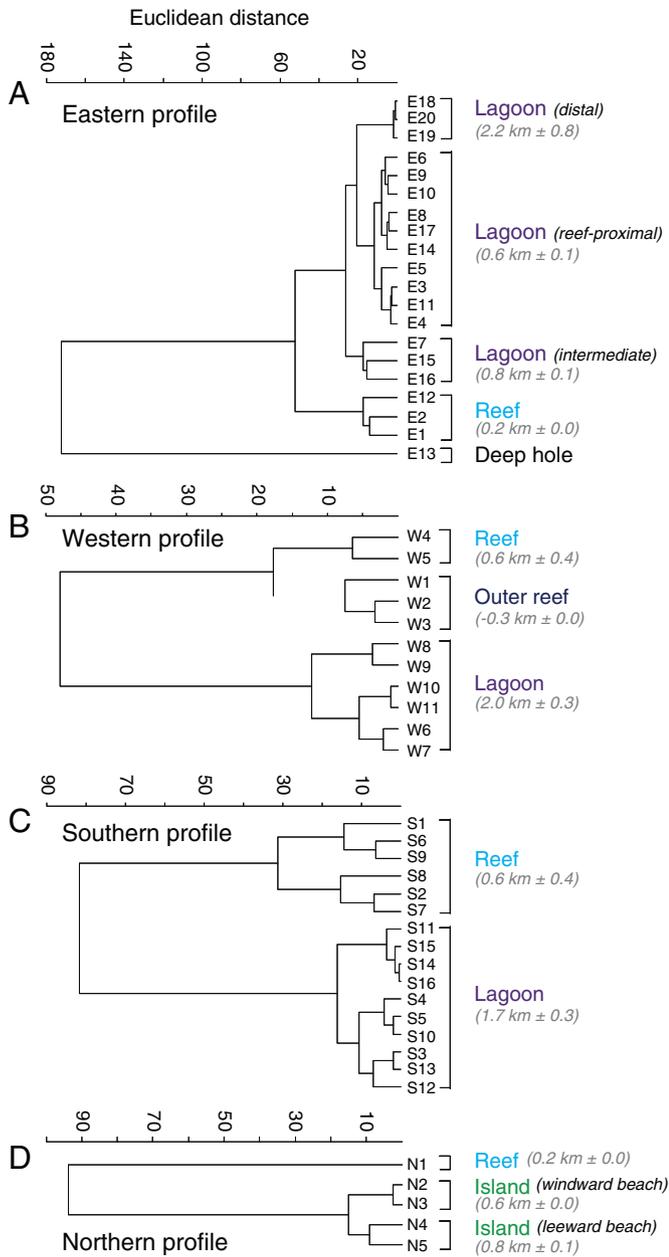


Fig. 6. Q-mode cluster analysis using Ward's method produced five main clusters related to physiographic zone: outer reef, reef, lagoon (including reef-proximal, intermediate and distal lagoon clusters in the eastern profile), deep hole and island (beach). Clustering is based on *Homotrema* counts from 52 surface sediment samples collected along the eastern (A), western (B), southern (C), and northern (D) lagoon profiles (Fig. 1B). Average distance from the reef for each cluster is indicated.

and storms, but the availability of individuals for transport cannot be ruled out. In the case of the southern profile, reef samples contained anomalously low concentrations due to the dominant 'southerlies' that cause increased wave intensity and enhanced sediment transport capacity along the southern shores of Wallis. Although the increased wave intensity likely detaches more *Homotrema* individuals in the southern region of the lagoon than elsewhere, the energetic wave climate is too strong for sediment deposition along the platform interior and shallow lagoon. The decrease in *Homotrema* concentration with increasing distance from the reef is in agreement with other studies (e.g., Mackenzie et al., 1965; Machado and Moraes, 2002) even though *Homotrema* concentrations are much lower here (e.g., 32–100 per cm³ in reef sediment) than in the Caribbean (e.g., 100–1000 per cm³; Pilarczyk and Reinhardt, 2012). MacKenzie et al. (1965) concluded

that *Homotrema* fragments are transported only over a short distance (e.g., <1.0 km in some areas), but this study documents their presence in sediments throughout the reef-tract including distances up to 3.0 km from the reef source.

Similar to the trend in total concentration, the taphonomic grade and fragment size also varied with distance from the reef source. Samples from outer reef and reef sites, where wave energy peaks, were characterized by high concentrations of extra large (>500 μm) fragments that were exceptionally-preserved. In contrast, lagoon and island (beach) samples contained smaller *Homotrema* fragments that were more taphonomically altered. In these more quiescent zones, extra large and exceptionally-preserved individuals were almost entirely absent; indicating the inability of normal wave activity to transport reef material >500 μm far into the lagoon. The marked transition recorded by the disappearance of exceptionally-preserved and extra large fragments occurred at a distance of 2.0 km on the eastern and western profiles, 1.4 km on the southern profile and 0.8 km to the north. Landward of the transition, only smaller, more bleached and rounded (moderately-preserved to highly-altered) fragments were present. While lagoon samples often contained low concentrations of well-preserved and large fragments, island beaches generally did not. Cluster analysis of the *Homotrema* data confirmed these findings by discriminating between reef, lagoon and island (beach) samples from all four profiles. In addition, clustering provided greater resolution for the eastern profile where lagoon samples were further discriminated by the distance from the reef (reef-proximal, intermediate, distal lagoon samples; Fig. 6A). Similarly, windward and leeward beaches (Fig. 1B) were discriminated, with windward beaches containing higher concentrations of *Homotrema* that were generally >500 μm (Fig. 6D). Patch reefs are another potential source of *Homotrema* but the lack of exceptionally-preserved individuals in lagoon samples indicates that patch reef-derived individuals are not a major contributor to surface sediment.

Zones of accumulation within a deep hole (Fig. 2) and reef channel (Fig. 5) were identified. For example, at a distance of ~1.0 km from the reef crest, the deep hole on the eastern side of the island contains higher concentrations of *Homotrema* fragments than any other sampled location. Despite being situated in the lagoon where surrounding samples are dominated by smaller, more altered fragments, deep hole samples contained fragments that are large and well- to exceptionally-preserved. This observation is contrary to those made by Yamano et al. (2002), who found that carbonate material in deep sections of lagoons are the result of in situ biota as opposed to transported reef material. Similarly, on the south side of the island, where average wave intensities are highest, detached *Homotrema* are washed from the reef into the deeper channel.

Sedimentological variability is difficult to assess in carbonate environments (e.g., Rankey et al., 2011) but *Homotrema* taphonomy is a useful indicator of the source (e.g., reef) and transport direction of sediments in these regions. Since *Homotrema* bleaches following detachment from the reef, it holds potential in estimating residence time of sediment in the lagoon, however, further studies regarding the rates and controls of bleaching (e.g., ultraviolet light, salinity, ocean acidification, pH) need to be conducted to better constrain controlling factors. Although all samples contained *Homotrema* fragments, taphonomically distinct clusters relating to distance from the reef source were revealed.

5.2. *Homotrema* as an overwash indicator

Most physical criteria for documenting storm and tsunami deposits have been developed in temperate climates where the contrast between soil and transported marine sediment is distinct and usually well preserved (e.g., Liu and Fearn, 1993; Hemphill-Haley, 1996; Sawai et al., 2008; Horton et al., 2009). On tropical coastlines, overwash deposits are often discontinuous, bioturbated, poorly preserved and therefore, difficult to distinguish from surrounding sediment (e.g., Goff

et al., 2011b; Yawsangratt et al., 2012). Benthic foraminifera have previously been used to document and interpret overwash deposits in these settings (e.g., Hawkes et al., 2007; Sugawara et al., 2009; Goff et al., 2011b; Yawsangratt et al., 2012) and studies employing the use of test taphonomic condition (e.g., test size, fragmentation, color, corrosion) have provided further insight into sediment transport histories (e.g., Hawkes et al., 2007; Satyanarayana et al., 2007; Pilarczyk and Reinhardt, 2012). For example, Goff et al. (2011b) found taphonomically distinct foraminiferal assemblages of paleo-tsunami deposits on Futuna Island. High concentrations of taphonomically unaltered (i.e., pristine) foraminifera peaked in tsunami sands; whereas, poorly preserved individuals were more dominant in surrounding sediment (Goff et al., 2011b).

Homotrema analysis enhances the taphonomic method because it constrains provenance to reef environments (MacKenzie et al., 1965; Machado and Moraes, 2002; Pilarczyk and Reinhardt, 2012). *Homotrema* analysis also provides a relative estimation of sediment residence time in the nearshore environment because it bleaches from red to whitish-pink following detachment from the reef (MacKenzie et al., 1965). In this way, *Homotrema* can be used to distinguish overwash deposits from their surrounding sediment. Island (beach) samples from Wallis contained the lowest concentrations of *Homotrema* fragments (<22 per cm³) that were generally highly-altered and small (<250 µm). This is in contrast to reef samples that contained an average of 50 fragments per cm³ that were dominantly exceptionally- to well-preserved and large (>250 µm). Overwash deposits at Wallis Island are therefore expected to contain higher concentrations of *Homotrema* that are larger and better preserved than fragments derived from surrounding sediment. This is in agreement with Pilarczyk and Reinhardt (2012) who documented an overwash deposit within marine ponds at Anegada, British Virgin Islands. The overwash deposit contained high concentrations (~1100 fragments per cm³ on average) of large and exceptionally- to well-preserved red to pink *Homotrema* fragments, suggesting the deposit was sourced from a modern reef to the north of Anegada and rapidly deposited by either a storm or tsunami (Pilarczyk and Reinhardt, 2012). By contrast, nearshore and beach sediments at Anegada were dominated by smaller fragments that were rounded and bleached due to increased residence time in the nearshore environment (Pilarczyk and Reinhardt, 2012).

6. Conclusions

Coastal sediments from Wallis Island contain *Homotrema* fragments that vary in concentration and taphonomic condition based on their proximity to the reef. Therefore, *Homotrema* taphonomy is a useful indicator of provenance and the direction of sediment transport, and shows promise in distinguishing overwash deposits from surrounding units. *Homotrema* taphonomic results discriminated between reef, lagoon and island (beach) samples. Reef samples were characterized by a high concentration of fragments that were large and exceptionally-preserved, maintaining the integrity of their chamber structure as well as their vibrant red color and angularity. Lagoon samples contained lower concentrations that were smaller and moderately-preserved; while island (beach) samples were characterized by very low concentrations of *Homotrema* fragments that were small, rounded and bleached. Owing to its abundance, predictable taphonomic deterioration and easy detection in reefal sediments, *Homotrema* taphonomic analysis has wide application to the assessment of sediment transport and overwash deposits in a variety of carbonate settings worldwide.

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