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Meta-Study of Carbonate Sediment Delivery Rates to Indo-Pacific Coral Reef Islands

Baptiste Ainési[1], **Gerd Masselink**[2], **and Paul Kench**[3]

[1]Geosciences Department, Ecole Normale Supérieure - PSL University, Paris, France, [2]School of Biological and Marine Sciences, University of Plymouth, Plymouth, UK, [3]Department of Geography, National University of Singapore, Singapore, Singapore

Key Points:

- We provide the first estimates of carbonate sediment delivery rates to 28 coral reef islands using all data available from the literature
- Sediment delivery to the reef islands occurs at a rate of c. 0.1 $m^3\ m^{-1}\ yr^{-1}$, but with substantial inter-island variability
- Where island building has been continuous through island history, long-term delivery rates provide valuable estimates for contemporary rates

Supporting Information:

Supporting Information may be found in the online version of this article.

Correspondence to:

G. Masselink,
gerd.masselink@plymouth.ac.uk

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Author Contributions:

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Visualization: Baptiste Ainési
Writing – original draft: Baptiste Ainési
Writing – review & editing: Gerd Masselink, Paul Kench

Abstract Coral reef islands are amongst the most vulnerable environments to sea-level rise (SLR). Recent physical and numerical modeling studies have demonstrated that overwash processes may enable reef islands to keep up with SLR through island accretion. Sediment supply to these islands from the surrounding reef system is critical in understanding their morphodynamic adjustments, but is poorly constrained due to insufficient knowledge about sediment delivery rates. This paper provides the first estimation of sediment delivery rates to coral reef islands. Analysis of topographic and geochronological data from 28 coral reef islands indicates an average rate of sediment delivery of c. 0.1 $m^3\ m^{-1}\ yr^{-1}$, but with substantial inter-island variability. Comparison with carbonate sediment production rates from census-based studies suggests that this represents one quarter of the amount of sediment produced on the reef platform. Results of this study are useful in future modeling studies for predicting morphodynamic adjustments of coral reef islands to SLR.

Plain Language Summary Low-lying coral reef islands are under threat of sea-level rise (SLR). However, when these islands are flooded, ocean waves can bring in sediment that can increase the island elevation. This would enable coral reef islands to better withstand flooding in the future. Knowing how much sediment is brought in will help in our understanding of future changes to these islands due to SLR. In this paper, we use data from 28 Indo-Pacific coral reef islands to compute sediment supply to the islands. We find that on average 0.1 m^3 of sediment (roughly 100 kg) is delivered each year for every meter of island shoreline. We further suggest that this implies that only one quarter of the sediments produced by the coral reef system is delivered to the island shoreline. Most of the sediment produced remains on the reef flat or is exported to the ocean or the lagoon. Our results will help future studies to predict more accurately how coral reef islands will adjust to SLR.

1. Introduction

Coral reef islands are accumulations of reef-derived carbonate material, deposited on coral reef platforms and atoll rims (Steers et al., 1977). Indo-Pacific atoll island development occurred through the mid-to-late Holocene, with the onset of island formation occurring from the oldest deposits at 5,500 years ago to more recent accumulations beginning around 500 years ago (Kench et al., 2023). Due to their low elevation and small aerial extent, coral reef islands are considered to be among the most vulnerable landforms to anthropogenic climate change and sea-level rise (SLR) (Oppenheimer et al., 2019). A global mean SLR of c. 0.25 m has already occurred and SLR is expected to accelerate with further increases in global mean sea level of 0.43 and 0.84 m by 2,100 according to RCP2.6 and RCP8.5, respectively Intergovernmental Panel on Climate Change (IPCC), (2022). Strong regional patterns in SLR are reported, with higher rates than the global average on Pacific tropical islands (Becker et al., 2012). Tropical storminess is also affected by climate change and tropical cyclones are expected to decrease in number, but increase in intensity (Bhatia et al., 2019; Walsh et al., 2019). Extreme sea level events due to storm waves and storm surge superimposed on global mean SLR will significantly increase coastal flood and erosion risk for coral reef islands (Storlazzi et al., 2015). According to Storlazzi et al. (2018), increased frequency and intensity of island overwash and groundwater contamination due to SLR will render most coral reef islands uninhabitable within decades.

These pessimistic prospects are drawn from "bathtub" and dynamic flood models based on the assumption that coral reef islands are geomorphologically inert. However, shoreline observations based on satellite data have highlighted that islands are highly dynamic and undergo continuous change in size, shape and position on the reef platform (Cuttler et al., 2020; Duvat, 2019; Kench, Ford, & Owen, 2018). Although coral reef islands are commonly assumed to be vulnerable to SLR and likely to be destabilized by wave-driven erosion (Connell, 2003; Roy & Connell, 1991; Woodroffe, 2008), coral reef island-shoreline observations have demonstrated that many islands have expanded over the last few decades (Duvat & Pillet, 2017; Kench et al., 2023; McLean & Kench, 2015). Small-scale physical and process-based numerical models have recently been developed to explore further the geomorphic response of coral reef islands to SLR (Masselink et al., 2020; Tuck et al., 2019). Both approaches suggest that coral reef islands may be able to maintain freeboard above rising sea level and that drowning is not the inevitable consequence of SLR. However, different trajectories across the full spectrum of island progradation to island destruction can occur, depending on extrinsic factors such as the rate of SLR and storm characteristics, and intrinsic physical factors such as island morphology, reef growth and sediment supply (Masselink et al., 2020).

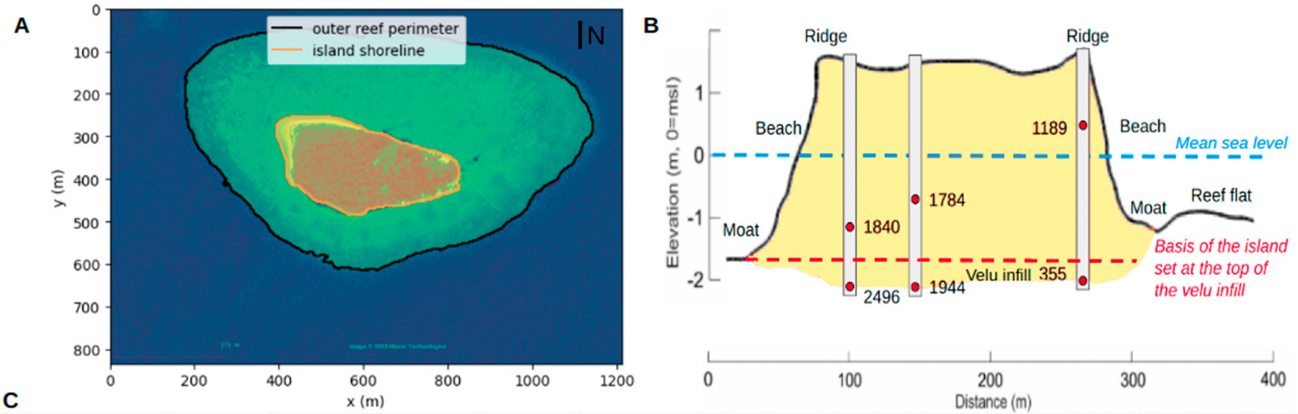
Sediment supply plays a critical role in shoreline adjustments of all depositional coastal environments, including coral reef islands. Many studies provide evidence of the close relationship between sand barrier development, sediment supply and sea-level history during the Quaternary (Fruergaard et al., 2015; Kennedy et al., 2020; Otvos, 2018). For example, Australian barrier systems prograded during the mid-to-late Holocene under rising sea level due to net onshore sediment transport on the order of 1 $m^3\ m^{-1}$ per year (Kinsela et al., 2016). Coral reef island adjustment to SLR is also likely to be highly dependent on the sediment supply from the reef system to the island. Indeed, modeling experiments showed that adding sediment reduces the erosive effects of rising water levels and accelerates the rate of crest elevation (Kench & Cowell, 2002; Tuck et al., 2021).

Coral reef islands are unique depositional systems as the sediments comprising islands are entirely derived from the skeletal remains of carbonate producing organisms from the surrounding reef flat and fore reef. While significant effort has been made to construct carbonate budgets for reef systems, and more recently sediment budgets on coral reefs (Lange et al., 2020; Morgan & Kench, 2014), there have been few attempts to resolve the sediment budget linkages between productive reef systems and islands, which is necessary to build, maintain and nourish coral reef islands (Browne et al., 2021; Perry et al., 2011). Notably, reef islands represent a millennial-scale sediment sink in the broader reef platform carbonate budget (Perry et al., 2011). However, the primary skeletal contributors that build islands shows considerable spatial variation, reflecting the relative ecological state of surrounding reefs, and the rate at which sediment is transferred to islands, reflecting the interplay between rates of sediment generation, the texture of sediment and the hydrodynamic processes able to entrain, transfer and deposit sediments on islands (Kench & McLean, 1996; Perry et al., 2011). However, little is known about the actual rates of sediment delivery to coral reef islands, which is pivotal to understand island physical dynamics and their potential adjustment to rising sea levels. Sediment supply is thus poorly constrained in morphodynamic models.

Reef island sediment reservoirs store a depositional record of island accumulation, which have yet to be systematically analyzed to reconstruct rates of sediment delivery. This study provides the first estimation of long-term sediment delivery rates to coral reef islands in the Indo-Pacific. Estimates are derived from the construction of geological sediment budgets using all available data on radiometric ages and island volumes from existing studies of island formation. Delivery rates corresponding to average rates over the history of the islands, from their initiation to present, are calculated. Specific objectives are to provide a set of delivery rates to islands that will allow future work to derive detrital sediment budgets on coral reef platforms and to help constrain sediment supply in morphodynamic island modeling. It will be shown that an order of magnitude of 0.1 $m^3\ m^1\ yr^1$ is delivered to coral reef islands, but with substantial inter-island variability. This value is compared to reef platform sediment production rates from census-based studies and we suggest that island sediment supply is approximately one quarter of the entire detrital sediment volume produced on reef platforms annually.

2. Method

Our approach is to estimate for each available coral reef island data set, the total volume of sediment that has accumulated over a certain amount of time, and estimate the rate of sediment delivery required per unit meter length of island shoreline. The method comprises four steps: (a) extraction of geometric island data; (b) computation of island sediment volume; (c) determination of sediment accumulation period; and (d) computation of sediment delivery rate (summarized for a lagoon island in Figure 1). A more detailed description of the method is provided in Sections 2.1–2.4.



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island	island surface area (m²)	shoreline perimeter (m)	island thickness (m)	oldest age (years BP)	window of accumulation (years BP)	average delivery rate (m³.yr⁻¹)	active delivery rate (m³.yr⁻¹)	average delivery rate per unit of shoreline length (m³.m⁻¹.yr⁻¹)	active delivery rate per unit of shoreline length (m³.m⁻¹.yr⁻¹)
Kandahalagalaa	63222 +/- 3000	1255 +/- 60	2.47 +/- 0.10	1840 +/- 180	1840 - 466 +/- 140	85.0 +/- 10.0	110.0 +/- 20.0	0.068 +/- 0.01	0.091 +/- 0.01

Figure 1. Application of the method to the island of Kandahalagalaa, Huvadhoo Atoll, Maldives. (a) Automatic classification of satellite image into atoll island, reef platform and lagoon using the Doodle Labeler (Buscombe & Ritchie, 2018). (b) North-South topographic profile of Kandahalagalaa (Kan) with radiometric ages (figure modified from Liang et al. (2022), their Figure 2d). (c) Table showing island parameters extracted from Liang et al. (2022) (island thickness, oldest age and window of accumulation), data measured from satellite image (island surface area and shoreline perimeter), and delivery rates to Kandahalagalaa computed using these data. The delivery rate has been computed from several profiles across the reef island.

2.1. Data Collection

Eighteen previous studies provided geochronological and topographic data for 28 coral reef islands distributed across the Indo-Pacific regions (Figure S1 in Supporting Information S1). Summary characteristics of each island and their adjacent reef platform are contained in Tables S3 and S4 in Supporting Information S1 and represent to the authors' knowledge all published data sets. In order to construct geological sediment budgets we only included islands where there is a minimum of 4 radiometric dates that temporally constrain the sediment reservoir. The identified islands show a wide range of sizes, ranging from 13,000 m^2 (Tutaga, in Funafuti atoll, Tuvalu)

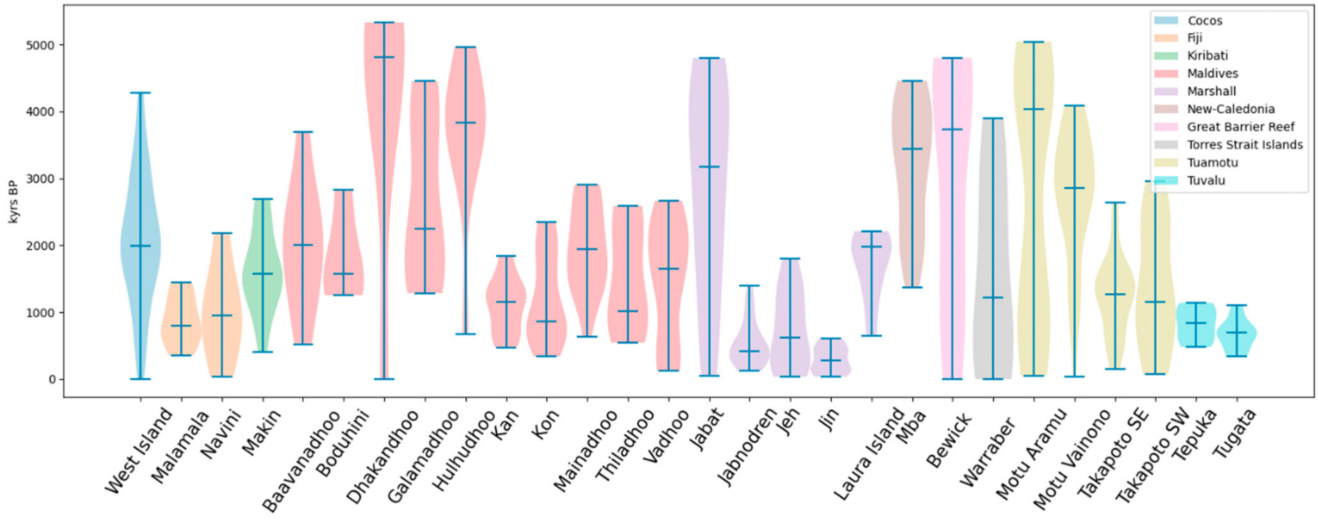

Figure 2. Distribution of radiocarbon ages measured on each atoll island.

to 9,000,000 m^2 (West Island, Cocos (Keeling) Islands). Some are inhabited (e.g., Vaadhoo, Huvadhoo atoll, Maldives; Laura, Majuro atoll, Marshall Islands), while others are uninhabited (e.g., Mba, New-Caledonia; Jin, atoll of Jaluit, Marshall Islands). Satellite images of all islands were collected using Google Earth and used to determine the spatial characteristics of each island and reef platform.

2.2. Island Sediment Volume

The volume of island sediment is calculated as the mean thickness of the unconsolidated sediment multiplied by the island surface area. The lower boundary of the island sediment reservoir differs between islands. On many islands sediments are deposited directly over consolidated reef flat or conglomerate platform forming a distinct boundary. However, on other islands the sediment reservoir lies above lagoonal infill deposits and, therefore, there is a transition between island and lagoon sediments. In these examples, the base of the island sediment volume was established at the top of the lagoon infill deposits (Figure 1b). Information on how we defined the base of each island is contained in Table S4 in Supporting Information S1. For over half of the studied islands, subsurface cores that reached the underlying platform or lagoon infill were collected providing information on the thickness of island sediments. However, on other islands, cores did not reach the underlying platform or lagoon infill and the basis of the unconsolidated sediment layer was set at the depth of the bottom of the deepest core. Using topographic profiles from each island and data from cores, the mean thickness of the sediment layer is estimated by measuring the area between the island surface and the sediment layer. This area is then divided by the width of the island to estimate the average thickness of sediments. When several profiles are available for one atoll island, the sediment thickness is calculated for each transect and then averaged. The surface area of the island is computed from the satellite images using a Python-based image processing tool, called Doodle Labeler (Buscombe & Ritchie, 2018). After training, the tool automatically labels pixels belonging to the island surface and discriminates them from the surrounding reef (Figure 1a). The volume of the island is then approximated by the surface area multiplied with the mean thickness of the island sediment. No consideration of textural variability among coral reef islands was made in the present work.

2.3. Sediment Accumulation Period

Radiocarbon dating of sediments from 28 islands is used to constrain the dates of island formation. For each island, the oldest radiocarbon age (ages labeled as outliers in the distribution were excluded, see Figure 2) from the base of the island sediment reservoir is used as the time for the beginning of sediment deposition, and this age is used to calculate the *average* sediment delivery rate (m^3 yr^{-1}) from the start of island building to present. However, for many islands, radiometric results show island building and sediment deposition ceased well before present. For example, no sediment younger than 1,000 yBP was found on the islands of Galamadhoo, Boduhini or Mba (Figure 2). Consequently, the time range of active deposition was also calculated, defined as the window ranging from the oldest age to the youngest age of island sediment, to capture shorter timeframes of island building. An *active* delivery rate is computed over the time range of active deposition.

2.4. Sediment Delivery Rate

The sediment supply to the island corresponds to the amount of sediment delivered to the island per unit of time. *Average* sediment delivery rates are calculated by dividing the volume of the island by the oldest age measured on the island, while *active* delivery rates are calculated dividing this same volume by the time range of active deposition (see Figure 1c). For example, at Kandahalagalaa, the oldest island age above the lagoon infill signaling the onset of island accumulation is 1,840 yBP (Figure 1b). Based on the calculated island volume (156,393 m^3) the *average* delivery rate to the island across 1,840 years is 85 m^3 yr^{-1}. However, the sediment age distribution ranged from 1,840 to 466 yBP indicating active island accumulation occurred over a narrower 1,374 years window and ceased approximately 500 years ago. Consequently, the delivery rate over this active island building window (1,374 years) is 110 m^3 yr^{-1}.

The delivery rates were then expressed as a delivery rate per unit length of island shoreline (m^3 m^{-1} yr^{-1}) (Figure 1c), referred to as the normalized delivery rate, and this rate will be used for assessing and modeling shoreline adjustments. Sediment delivery is assumed to occur around the entire platform; therefore, delivery rates are divided by the whole island shoreline perimeter. A distinction was made for linear reef rim islands where there is clear evidence that the island builds seawards from the lagoon shoreline (Laura Island, Marshall Islands; Takapato, Tuamotu; West Island, Cocos). For these islands, delivery rates are divided by the length of the oceanward shoreline, as reef-derived sediment transport is expected to mainly take place from the oceanward reef to the shoreline. The current island perimeter was used for computing delivery rate per unit length of shoreline. We acknowledge that the existing island perimeter would not be representative of shoreline length as the island expanded on its reef surface. Therefore normalized delivery rate is an underestimate for early stages of island development. However, we use this value as a conservative baseline to reflect the existing island sediment linkage, for comparison with current rates derived from sediment budget investigations, and to configure future geomorphic modeling scenarios. Sediment delivery and island growth rate are assumed constant over bracketed time period and average delivery rates provide thus valuable estimates for contemporary sediment delivery rates. This assumption is further discussed in Section 3.

All parameters used in the computation of sediment delivery rates have an associated, and largely indeterminable, uncertainty. The uncertainties are assumed to have a Gaussian distributions with estimated standard error of 10% for sediment thickness, surface area and reef length, and of 20% for time ranges. These uncertainties were then propagated into the final estimates, providing uncertainties for the computed delivery rates (Table S1 in Supporting Information S1).

3. Result and Discussion

The radiometric data show that the onset of island formation across the Indo-Pacific occurred throughout the mid-to late-Holocene with no apparent differences in timing between reef regions (Figure 2). Earliest ages of island evolution are between 4,000 and 5,500 years ago with examples evident in all the major reef provinces examined. Notably, a number of islands have also formed much later in the Holocene, within the last 1,000 years. Closer examination of the age distribution of sediments in each island highlights temporal variability in the onset, accumulation window and termination of island formation during the mid-to late-Holocene (Figure 2). Some islands show evidence of continued sediment accumulation from the time of initial deposition to the present, whereas others suggest island formation ceased well before present. For example, on Jeh (Marshall Islands) and Navini (Fiji) island margin sediments are modern, which suggests there is still active delivery of sediment to shorelines. In contrast, on Galamaadhoo and Boduhini (Maldives) and Mba (New-Caledonia) no sediment younger than 1,000 yBP was dated, implying cessation of island development at that time.

It is also apparent that the style of accumulation varies significantly. For example, relatively uniform age distributions are found on some islands (e.g., Malamala in Fiji and Jabat in the Marshall Islands), indicating sediment deposition occurred at a near-constant rate across the window of island accumulation. However, on many islands the age distributions are not uniform, suggesting episodic deposition characterized by pulses of rapid sedimentation, interspersed with periods of low sedimentation rates. On Motu Aramu (Tuamotu), 50% of ages occur in a narrow time window (5,000–4,000 yBP), while the remaining ages are spread more continuously across the 4,000 years to present.

Summary data on island sediment reservoirs and rates of sediment delivery (Figure 3, Table S1 in Supporting Information S1) reveal several distinct features. First, the majority of islands have a sediment thickness ranging from 1 to 2.5 m, though four islands have island sediment thickness greater than 3.5 m (Mba, Malamala, Navini and Bewick). Second, island sediment volumes range across three orders of magnitude from 21,634 m^3 on Tutaga (Funafuti atoll) to 15,686,133 m^3 on West Island (Cocos (Keeling) Islands). Third, a strong positive correlation is found between sediment delivery rate in $m^3\ yr^{-1}$ and island surface area (Table S2 in Supporting Information S1). Sediment delivery rates to islands scale with increasing island size (Table S2 and Figure S2 in Supporting Information S1) because increased reef platform area leads to increased sediment productivity (and thus sediment availability) as well as available accommodation space. The mean delivery rate for island size classes of >100 ha, 99−10 ha and <10 ha are 2,137, 257 and 51 $m^3\ yr^{-1}$ respectively. Normalized by island perimeter length, to account for large differences in island size, the data indicate that the average delivery rate to islands has a mean value of 0.118 $m^3\ m^{-1}\ yr^{-1}$ and ranges from 0.017 to 0.37 $m^3\ m^{-1}\ yr^{-1}$ (Table S1 in Supporting Information S1). The mean upper delivery rate is 0.151 $m^3\ m^{-1}\ yr^{-1}$ (range of 0.024–0.53 $m^3\ m^{-1}\ yr^{-1}$).

Collectively the meta-analysis of island geological sediment budgets indicates mean annual delivery of 646 ± 1,010 $m^3\ yr^{-1}$ to islands or 0.118 ± 0.092 $m^3\ m^{-1}\ yr^{-1}$. However, results show considerable variability

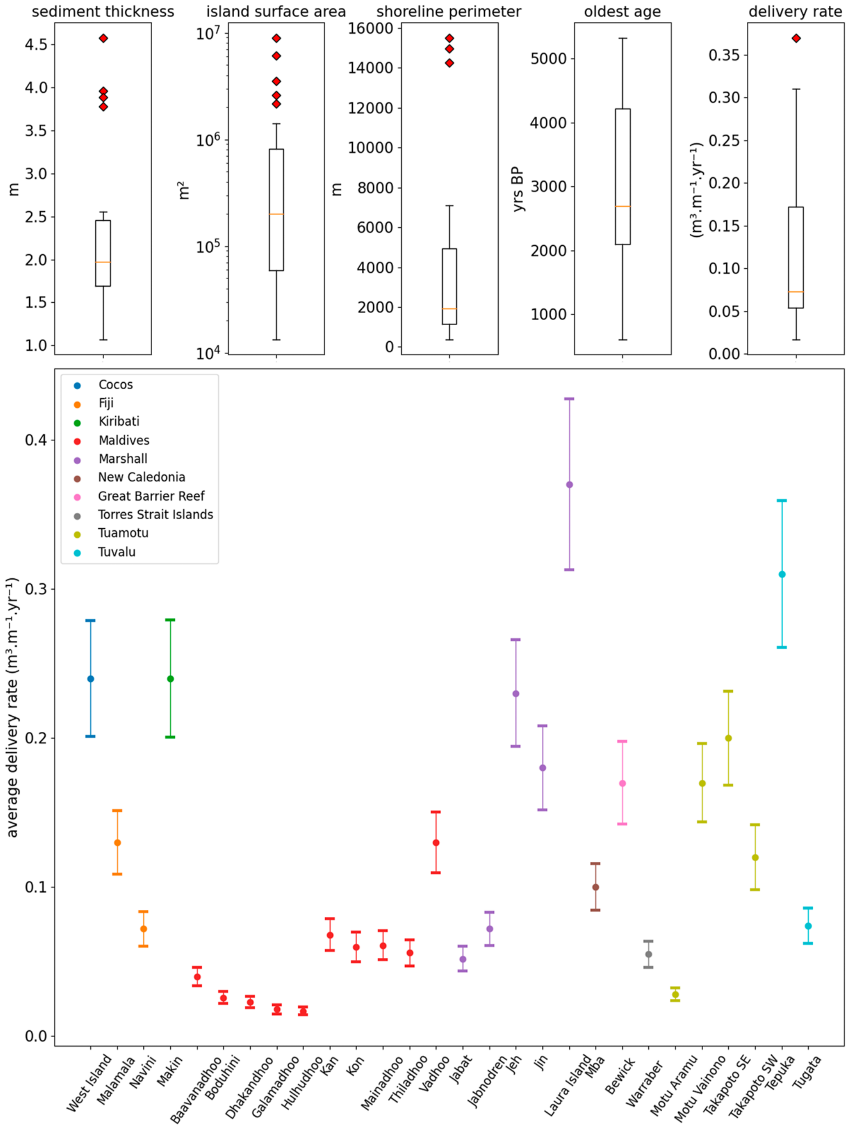

Figure 3. Average delivery rates per meter unit width displayed for each coral reef island, average delivery rate distribution and four parameters distribution: sediment thickness, island surface area, shoreline perimeter and oldest island age.

which likely reflects intrinsic differences in sediment generation and transfer to islands between reef systems that is unique to biogenic carbonate sediment systems. Where geochronological data demonstrate relatively uniform island growth, delivery rates calculated in this study are likely to provide a first order estimate of contemporary sediment supply to islands, and implies active sediment delivery from the surrounding reef is ongoing. However, on many islands the geochronological data show the accumulation history has not been uniform. While interpretations of the age distributions may be subject to the density of ages resolved in each study, the episodic nature of deposition is consistent with contemporary understanding of sediment generation and delivery mechanisms in reef systems (Bayliss-Smith, 1988).

A unique aspect of coral reef island landforms is that sediments are entirely composed of the skeletal remains of carbonate secreting organisms (Perry et al., 2011). The rate of delivery of sediments to islands is, therefore, dependent on the diversity, abundance and growth rates of carbonate secreting organisms (both primary framework builders and secondary producers), the efficacy of bioerosion processes that breakdown primary framework (coral), and the hydrodynamic regime that selectively sorts and transports sediments to islands (Browne et al., 2021; Perry et al., 2011). Consequently, the sediment system is susceptible to naturally occurring or anthropogenically forced disturbance that disrupts sediment delivery entirely or temporarily.

Sediment delivery rate and sediment composition are also likely to have been modulated by changes in sea level during the Holocene period, in particular the well-documented 0.5–1.0 m fall in sea level during the mid-to late Holocene (Kench et al., 2009). For example, (a) colonization of emerging reef flats by benthic foraminifera has been implicated in several studies in transforming the sediment reservoir on reef systems (Perry et al., 2011; Yamano et al., 2000), but such new sediment types may not necessarily be transported to islands; (b) emergence of the reef flat may significantly alter the potential for sediments to be physically transported towards islands due to significantly reduced wave forcing due to smaller water depths; and (c) emergence of islands may even elevate them above the active sediment delivery pathway. Collectively these changes in the sediment system may cause island building to cease, as reflected in a number of islands in this study.

Episodic island accumulation is also likely to reflect disturbances in the sediment generation and supply system. For example, bleaching events associated with anomalously high water temperatures can cause the death of live corals, and in combination with increased bioerosion, can create a pulse in sediment availability (Perry et al., 2011). For example, in the Maldives, Perry et al. (2020) identified an increase in sediment generation by several taxa from 0.5 kg $CaCO_3$ m^2 yr^{-1} to 3.7 kg $CaCO_3$ m^2 yr^{-1} following a bleaching event in 2016. However, if such shifts are short-lived (<3 years), they are unlikely to be recorded in island stratigraphy. In contrast, longer period variations (>10 years) may be recorded in the island depositional sequence as shown in Tepuka (Funfauti atoll) where episodic changes in dominant sediment type was observed, from foraminifera to coralline algae (Kench et al., 2014). Lastly, intense storms and cyclones are able to have catastrophic impacts on the living ecology of reef systems, yielding large pulses of sediment that can form or add to island sediment reservoirs (Bayliss-Smith, 1988). For example, at Tutaga (Funafuti atoll) episodic storms transported large coral blocks from the forereef to the reef flat to build the island (Kench, McLean, et al., 2018). On the eastern side of the same atoll, Cyclone Bebe (1972) delivered more than 1.4×10^6 m^3 of coral rubble to the reef surface (Maragos et al., 1973), which ultimately increased island area by 10%–20% (Baines & McLean, 1976; Kench, McLean, et al., 2018). Similar observations of storm-induced activity have been responsible for episodic island accumulation in the Marshall Islands (Blumenstock et al., 1961; Ford & Kench, 2016; Kench et al., 2022) Ballast Island, Japan (Kayanne et al., 2016), and Lady Elliot Island in the Great Barrier Reef (Chivas et al., 1986).

The island sediment volumes and rates of sediment supply calculated in this study provide first-order estimates that can be related to estimates of contemporary sediment production on reef surfaces. It is important to note that there have been few attempts to quantify detrital sediment generation on coral reefs and no field-based investigation of rates of sediment delivery to island shorelines. Census-based approaches have been adopted to determine the net calcium carbonate budget of reef platforms (Perry et al., 2012) and in such studies the generation of detrital material is treated as a loss term. A number of studies have identified the production rate of benthic organisms and the role of specific bioeroding organisms in breaking down coral framework to detrital sediment (Hart & Kench, 2007; Morgan & Kench, 2016a; Perry et al., 2015). More recently, (Perry et al., 2023) has generated holistic estimates of total detrital sediment generation at sites in the central Indian Ocean yielding site-specific rates ranging from 0.5 to 4.5 kg m^{-2} yr^{-1}. We take the midpoint of 2.5 kg $CaCO_3$ m^{-2} yr^{-1} as a typical reef-average value for sediment production on atoll reef platforms. Using satellite images of atoll islands in this study, we find a geographically-averaged shallow reef width to be of 240 m. This width covers inner reef flat, outer reef flat and reef crest geomorphic zones. We assume the fore reef productivity is the same as that on the reef platform and consider a 30 m wide fore reef (extending to 10 m depth assuming a 1:3 slope). We thus consider a value of 270 m for the reef sediment generation width covering the reef flat, reef crest and fore reef. We multiply the assumed typical sediment production value in unit square meter by the average reef width, yielding a sediment production of 680 kg $CaCO_3$ per unit meter reef length per year.

The geographically-averaged value for sediment delivery rates is 0.118 m^3 m^{-2} yr^{-1} (Table S1 in Supporting Information S1) and using a value for the coral density of 1.50 g cm^{-3} (Morgan & Kench, 2012) yields an average delivery rate of 177 kg $CaCO_3$ m^{-1} yr^{-1}. The sediment supply to Indo-Pacific coral reef islands therefore represents on average one quarter of the sediment production on the reef platform. The estimated rate of sediment supply is thus significantly lower than the rate of sediment production. Indeed, sediment deposition on islands is one among several identified sediment sinks: Morgan and Kench (2014) found high off-reef export of 127,120 kg each year at Vabbinfaru reef, Maldives. This represents 59% of the 214,000 kg of sediments produced each year at Vabbinfaru (Morgan & Kench, 2016a). Less than half of the sediments produced remain on the reef platform and a substantial part of it is likely to be trapped in submarine reefal reservoirs without reaching the island. Morgan and Kench (2016b) found further strong disparity in the composition and texture of sediment assemblages between submarine reefal reservoirs and island deposits: coral-dominated very well sorted medium sand was found on the island beach whereas coarser and moderately sorted coral rich sand was collected in the lagoon. This disparity between reef and island sediments suggests that atoll islands are very selective sediment sinks, storing only a small fraction of the reef sediment production while the majority remains in submarine reservoirs on the reef flat, lagoon, or is exported off reef.

Significantly, our results provide an empirical basis to support ongoing work to further constrain sediment delivery rates in models of morphodynamic adjustment of atoll islands to SLR. However, contemporary sediment delivery rates to atoll islands are likely to change in the incoming decades with climate change and SLR. As described in-depth in Browne et al. (2021) and in Perry et al. (2011), sediment production and supply to the island will depend on how reef ecology and sediment transport will respond to anthropogenically driven environmental changes such as SLR, increasing sea surface temperatures, change in storm patterns, change in water quality (e.g., acidification, eutrophication) and over-fishing. Rates calculated here might thus be used as a starting point for building sediment supply projections in the context of anthropogenic environmental changes.

This study provides the first estimate of long-term sediment delivery rates to coral reef islands, using all available data from the literature. Results point towards a rate of c. 0.1 $m^3\ m^{-1}\ yr^{-1}$, but with a substantial variability among reef islands (range of 0.017–0.37 $m^3\ m^{-1}\ yr^{-1}$). Comparison between sediment delivery rates and sediment production rates using values for the Maldivian Archipelago suggests that the sediment supply to coral reef islands is on average one quarter of the amount of carbonate sediment produced on the reef platform. This provides insights into one of several sediment sinks in reef platform sediment budget. Where island building has been continuous, long-term sediment delivery rates values are a good starting point for building sediment projections into morphodynamic modeling of atoll island evolution due to climate change. These projections would help constraining further morphodynamic models and better understanding atoll islands adjustments in response to climate change and SLR, and help optimize adaptation strategies.

Data Availability Statement

No new data were used in this study. The data on which this article is based are available in East et al. (2018), Ford et al. (2020), Kench et al. (2005, 2012, 2014, 2018, 2020, 2022), Liang et al. (2022), McKoy et al. (2010), Montaggioni et al. (2019, 2023), Owen et al. (2016), Woodroffe et al. (1999), Woodroffe and Morrison (2001), Woodroffe et al. (2007), Yamano et al. (2014), and in Yasukochi et al. (2014).

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