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Coral Mitigates High-energy Marine Floods: Numerical Analysis on Flow–Coral Interaction

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ABSTRACT

This paper investigates the effect of coral reef roughness on mitigating marine floods by using numerical analysis. The study includes two ocean bathymetries — idealised bathymetry with 1% gradient and real bathymetry — for Gold Coast, Australia. The results indicate that characteristics of the marine flood (wave height and period), coral roughness, and shape of the bathymetry are key to the mitigation of marine floods. Wave height reduction behind the reef and at the shore increases with the incident wave height of the marine flood. The maximum reduction behind the reef is around 60% for both bathymetries for the incident wave height of 4 m. When the incident wave period increases from 10 min to 20 min, the wave height reduction increases to 60% but increases from 20 min to 40 min, decreasing the reduction to as little as 3% behind the reef for the ideal bed condition. However, the marine floods caused by longer period waves can be slowed by higher coral roughness compared to the floods caused by relatively shorter period waves. The wave force reduction behind the reef increases with the incident wave height of the marine flood. The wave force reduction is greater than the wave height reduction behind the reef.

KEYWORDS

Marine flood; roughness; coral; numerical modelling; long-period waves

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1. Introduction

Coral reef ecosystems thrive in tropical waters of the Pacific, Indian and Caribbean oceans (Pandolfi *et al.*, 2003). Coral reefs are considered a natural barrier system against marine floods caused by high-energy wave events such as tsunamis and storms (Kunkel *et al.*, 2006; Beck *et al.*, 2018). Complex hydrodynamic processes including wave reflection, refraction and breaking occur near and over coral reefs. Reef structure morphology, flow depth over the reef, reef width and coral surface roughness are some of the important parameters that help to assess wave energy reduction (Brander, 2004). Other parameters, such as the location of the coral reef relative to wave source, coral health and coral continuum, also influence the performance of the coral reef in wave energy reduction (Cochard *et al.*, 2008). The effect of coral reefs on wave energy mitigation reduces where the reefs are located close to the shoreline or where the wave heights and wave lengths are considerably large (Kunkel *et al.*, 2006). Waves propagating over a coral reef surface undergo a complex transformation, mainly because of rapid change in water depth, irregularities of reef geometry, and variability in surface roughness conditions (Brander, 2004), which creates a complex hydrodynamic environment (Philpott, 2016). Due to changes in ocean bathymetry, waves shoal, reflect, refract and break while propagating over the reef structure (Hardy *et al.*, 1990). Reef flats have surface roughness due to the presence of coral growth and the continual sedimentation process by biological and wave depositional processes (Flood, 2011). The surface roughness of coral varies considerably with types of coral since coral formation and growth are influenced by biological and morphological processes (Gourlay, 1996). Corals branch out in the presence of sunlight (Chappell, 1980), and slow-growing globular coral structures are observed where the light availability is limited. Conversely, hydrodynamic stresses have adverse effects on the coral morphology (Chappell, 1980), especially on branching corals such as staghorn corals, which are dislodged and damaged due to wave forces (Harmelin-Vivien, 1994). However, the globular corals can withstand damaging wave forces without being severely affected (Chappell, 1980). These constant changes in coral structure influence the overall roughness. In their study, Madin and Connolly (2006) provided a general framework for understanding and predicting the effects of hydrodynamic disturbances on coral reef communities with the coefficient of drag. Undoubtedly, these findings provide an insight into reef hydrodynamics; however, there is still a lack of fundamental studies such as numerical analysis and controlled experimental investigations to demonstrate the mechanism of wave energy dissipation over coral reefs. Such studies could also provide a better understanding of the role of coral reefs in the mitigation of marine floods. This study aimed to elucidate the effect of the roughness of coral reefs on mitigating marine floods in numerical modelling. A one-dimensional depth-integrated numerical model was developed to simulate the long-period marine flood propagation under the effect of coral reef roughness. The numerical results were analysed to report the effect of coral reefs' roughness on the reduction of wave height and wave force behind the reef and at the shoreline against the incident wave characteristics, and the effect of bed slope.

2. Material and Methods

2.1. Governing Equations

A depth-integrated modelling approach was used to simulate marine flood propagation by long-period waves. The governing laws were the conservation of mass and momentum (Kowalik, 2012). The representative forms of those laws are given as:

Continuity equation

$$\frac{\partial \xi}{\partial t} + \frac{\partial Q}{\partial x} = 0 \qquad (1)$$

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Momentum equation

$$\frac{\partial Q}{\partial t}+\frac{\partial\left(\frac{Q^2}{h}\right)}{\partial x}+gh\frac{\partial \xi}{\partial x}+\frac{\tau}{\rho}=0 \qquad (2)$$

where ξ is the sea surface elevation, t the time, x the longitudinal co-ordinate, Q the discharge along the x-direction per unit width, h the sea depth, g the gravitational acceleration, τ the bottom shear stress along the x-direction, and ρ the seawater density (Yasuda, 2019). The bottom shear stress can be modelled by Nandasena *et al.* (2008):

$$\tau=\frac{\rho g n^2}{h^{\frac{7}{3}}}Q^2 \qquad (3)$$

where n is the bed resistance given in Manning's roughness coefficient.

For seabed roughness without coral, the value of Manning's roughness of 0.025 s/m$^{1/3}$ (Goto *et al.*, 1997) was considered in the model. The coefficient of friction (f) for the coral reef zone in the shallow sea (depth from 30 m to 60 m) ranging between 0.05 m/s and 0.40 m/s and thus the corresponding Manning's roughness (n) ranging between 0.1 s/m$^{1/3}$ and 0.25 s/m$^{1/3}$ (Cialone *et al.*, 2008) were considered in the model. The density of seawater was 1029 kg/m³ in the model (Nandasena *et al.*, 2008).

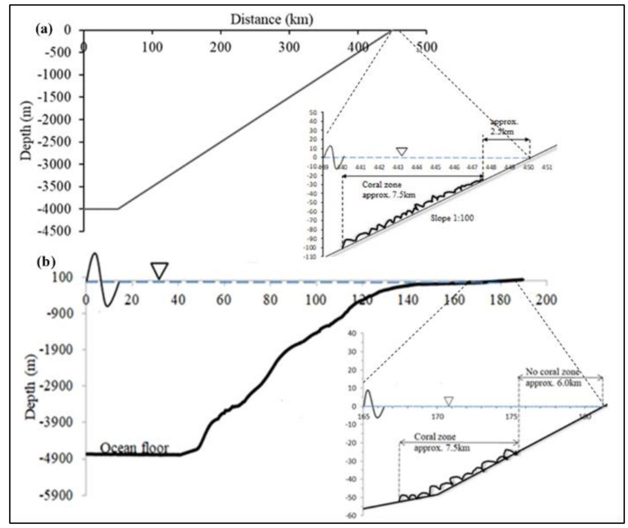
2.2. Coral Bed Profile

Two bed profiles were considered, namely an idealized profile with a constant bed slope and a profile for Gold Coast, Australia, based on the Great Barrier Reef depth and elevation model (GBRDM). Fig. 1a displays the idealized ocean bed profile, which consisted of a flat ocean floor at a depth of 4,000 m and extending from origin to a horizontal distance of 50 km. The horizontal profile was identified as a linear zone and was the origin of the wave generation (generation boundary). Beyond the linear zone, the bed had an increasing slope with a constant gradient of 1 in 100. Fig. 1b represents the actual bed profile for Gold Coast, Australia. The profile was drawn using the actual bathymetry elevation contours, made available by James Cook University and The Reef and Rainforest Centre Australia as part of their project 3D GBR (Great Barrier Reef): high-resolution depth model for the Great Barrier Reef and the Coral Sea. The bed consisted of a near-horizontal abyssal plain at 4,900 m depth for a distance of about 50 km, beyond which the bathymetry increased from deep ocean to about 200 m depth within a 100 km horizontal distance and at an average gradient of 1 in 20 (5%). Beyond 100 m depth, the bathymetry increased gently, with the slope between 50 m depth and the shoreline being less than 0.5%. The coral zone was defined between depths of 50 m and 25 m to have similar coral width, as in case of the Fig. 1a. A lagoon area, behind the reef, is depicted in Fig. 1b; however, due to the gentle slope of the Gold Coast profile, the extent of the lagoon water was almost three times wider than that in the idealized case (Fig. 1a).

2.3. Model Set-up

A finite difference scheme with a staggering space grid and leap-frog time method was used to solve the governing equations. The discretization sizes were Δx = 10 m and time step Δt = 0.04 s and allowed for non-dispersive wave propagation (Kowalik, 2012). The water depth at the wave generation boundary was at least 4000 m, depicting the marine flood origination in the deep sea. Flood waves were modelled by long-period waves with T_p = 10 min (relatively short), 20 min (moderate) and 40 min (relatively long). The wave height at the generation boundary was set to H_b = 0.5.

Figure 1: Bed profiles for simulation: (a) cross-section of the idealized bed at 1% gradient, (b) cross-section of Gold Coast from GBRDEM. Insets show the location of the coral reef in the bed. The wave generation boundary was at 0 m. 1.0 m, 2.0 m, and 4.0 m. For each bed profile and flood characteristics, three different cases were analysed.



Case 1: seabed without corals – a constant bed roughness of Manning's (n) = 0.025 s/m$^{1/3}$ (Levin and Nosov, 2019).

Case 2: seabed with corals of low resistance – a bed roughness of Manning's (n) = 0.025 s/m$^{1/3}$ for the seabed, and corals with Manning's roughness (n) of 0.1 s/m$^{1/3}$ (Cialone *et al.*, 2008).

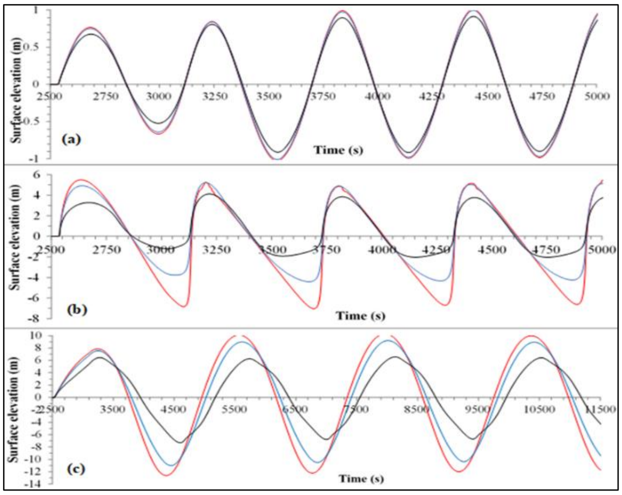
Case 3: seabed with corals of high resistance – a bed roughness of Manning's (n) = 0.025 s/m$^{1/3}$ for the seabed, and corals with Manning's roughness (n) of 0.25 s/m$^{1/3}$ (Cialone *et al.*, 2008).

The model predicted the temporal and spatial variation in sea surface elevation (i.e. wave height) and water particle velocity (flow velocity) in the computational domain (Fig. 1). The percentage reduction of wave height and wave force (hydrodynamic force) behind the coral reef and at the shoreline was estimated relative to the no coral case. The following key assumptions were made for the model. The waves were purely sinusoidal and long-period at the wave generation boundary. The flow above the corals and the flow through the corals were not considered separately (i.e. the two-layer flow was not considered). The energy dissipation of waves was only caused by the roughness of the corals and seabed. The length of the coral reef was infinitely long parallel to the shoreline. The coral reef was considered parallel to the shoreline and perpendicular to wave propagation. Corals were of uniform roughness, and this was modelled by Manning's roughness coefficient.

3. Results

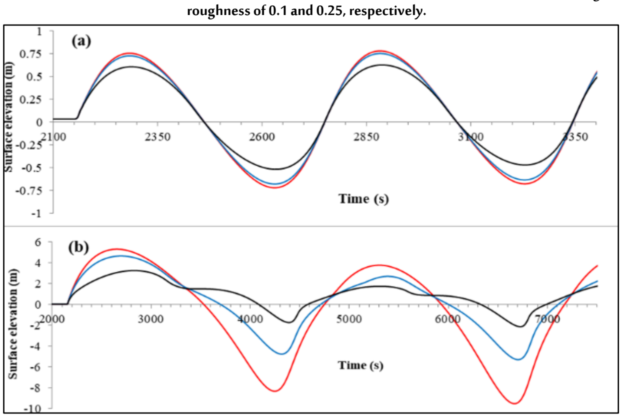
The effect of coral roughness on mitigating marine floods was assessed by calculating the percentage reduction in wave height at the end of the coral zone (i.e. at 25 m sea depth behind the reef) and at the shoreline compared with the no coral condition. Wave energy is proportional to the square of the wave height (Sorensen, 2006); therefore, the assessment of the wave height at the end of the coral zone determines the effect of coral roughness on flood energy reduction. Fig. 2 displays the temporal variation in the sea surface behind the reef for the wave characteristics and coral roughness on the idealized bed profile.

Figure 2: Temporal variation in sea surface elevation behind the reef on the idealized bed profile (Fig. 1a). (a) H_b = 0.5 m and T_p = 10 min, (b) H_b = 4 m and T_p = 10 min, and (c) H_b = 4 m and T_p = 40 min. The red line shows the case without coral, and the blue and black lines show the cases of Manning's roughness of 0.1 and 0.25, respectively.



When the roughness of the reef increased, the fluctuation of the sea surface decreased. But it was not significant for marine floods with a small wave height and a relatively shorter wave period (Fig. 2a). The roughness effect of the sea bed and coral increased when the sea depth decreased (Eq. 3). Therefore, theoretically, the effect of coral roughness on wave trough is significant. In this study, this effect was evident for larger waves despite their wave period (Fig. 2b–c). For small waves, it was not significant, as the temporal change in the sea depth caused by the fluctuation of the sea surface was minimal (Fig. 2a). Wave deformation was increased when wave height increased. With the travel distance, the sinusoidal shape of the waves changed for the high waves with a relatively shorter wave period (Fig. 2b). When the high waves with a relatively longer wave period moved over the coral reef with higher roughness, they were subjected to phase lag (Fig. 2c). This indicated that marine floods with a longer period can be slowed by higher coral roughness. Fig. 3 shows the temporal variation in the sea surface behind the reef for the wave characteristics and coral roughness on the Gold Coast bed profile.

Figure 3: Temporal variation in sea surface elevation behind the reef on the Gold Coast bed profile (Fig. 1b). (a) H_b = 0.5 m and T_p = 10 min at the generation boundary, and (b) H_b = 4 m and T_p = 40 min. The red line shows the case without coral, and the blue and black lines show the cases of Manning's roughness of 0.1 and 0.25, respectively.



The bed profile has a convex shape compared to the idealized bed (Fig. 1a). The effect of the sea bed was significant; therefore, a flatter wave crest and steeper wave trough were observed for the high waves with a relatively longer wave period (Fig. 3b). The reef has a relatively shallow sea depth compared to that of the idealized bed (Fig. 1a); this resulted in a significant reduction in wave height behind the reef (Fig. 3). These observations confirmed that wave characteristics of the marine flood, coral roughness, and shape of the sea bed are key to controlling the mitigation of marine floods. The effect of coral roughness on mitigating the marine flood on the idealized bed is displayed in Fig. 4 and Fig. 5.

Figure 4: Marine flood mitigation potential of the coral reef on the idealized bed profile (Fig. 1a) with wave height. (a, b, and c) wave height reduction behind the reef and (d, e, and f) wave height reduction at the shoreline compared to the case without reef. The thick and dotted lines show the results for Manning's roughness of 0.25 and 0.1, respectively. H_b and T_p are the wave height and wave period at the generation boundary, respectively.

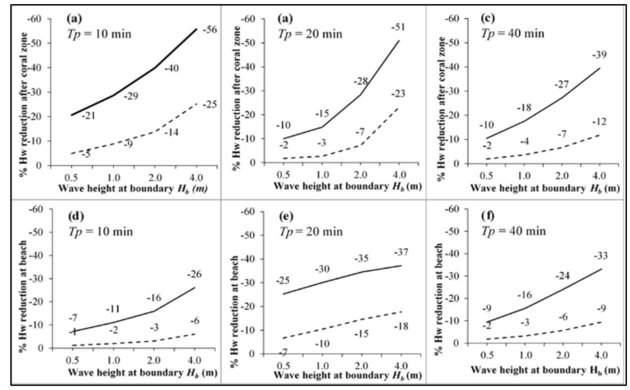
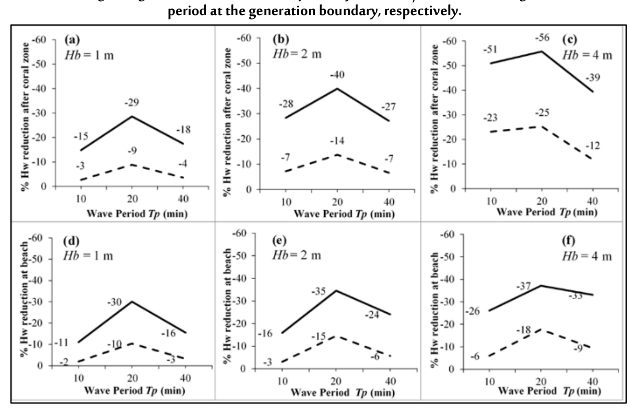


Figure 5: Marine flood mitigation potential of the coral reef on the idealized bed profile (Fig. 1a) with wave period. (a, b, and c) wave height reduction behind the reef and (d, e, and f) wave height reduction at the shore compared to the case without reef. Thick and dotted lines show the results for Manning's roughness of 0.25 and 0.1, respectively. H_b and T_p are the wave height and wave period at the generation boundary, respectively.



Regardless of the wave period, the coral reef reduced the wave height behind the reef and at the shoreline with the magnitude of the marine flood (Fig. 4). When the roughness was increased twofold, the reduction in wave height was increased from 2.2 times to as high as five times behind the reef for the cases studied. The reduction in the wave height at the shoreline was smaller compared to that behind the reef since the bed roughness from the reef end to the shoreline was not higher than that from the reef. The relationship between the wave period and the effect of coral roughness on mitigating the marine flood was complex (Fig. 5). When the wave period increased from 10 min to 20 min, the reduction in wave height increased, whereas during the wave period from 20 min to 40 min, the reduction in wave height decreased (Fig. 5). Despite the wave height, the marine flood with a wave period of 20 min was largely mitigated by the coral reef on the idealized bed (Fig. 1a). Table 1 shows the effect of coral roughness on mitigating the marine flood on the Gold Coast bed. The percentage reduction in wave height was similar to the case of the idealized bed (Fig. 4).

Table 1: Marine flood mitigation potential of the coral reef on the Gold Coast bed profile (Fig. 1b). Wave height reduction behind the reef and at the shoreline compared to the case without reef. H_b and T_p are the wave height and wave period at the generation boundary, respectively.

	Wave height reduction %					
	The roughness of corals (Manning's roughness coefficient = 0.1)					
H_b (m)	Behind the coral zone			At the shore		
	T_p = 10 min	T_p = 20 min	T_p = 40 min	T_p = 10 min	T_p = 20 min	T_p = 40 min
0.5	4	4	7	2	3	11
1.0	8	6	12	4	5	16
2.0	16	13	20	7	7	21
4.0	28	26	33	10	10	22
	The roughness of corals (Manning's roughness coefficient = 0.25)					
H_b (m)	Behind the coral zone			At the shore		
	T_p = 10 min	T_p = 20 min	T_p = 40 min	T_p = 10 min	T_p = 20 min	T_p = 40 min
0.5	16	18	26	4	11	32
1.0	33	26	36	20	16	36
2.0	51	37	49	28	24	40
4.0	65	57	64	36	35	43

When the wave height increased, the percentage reduction in wave height behind the reef and at the shoreline increased. The reduction in wave height was greater behind the reef than at the shoreline. When the wave period increased from 10 min to 20 min, the reduction in wave height decreased, whereas when the wave period increased from 20 to 40 min, the reduction in wave height increased. This is contrary to the case of the idealized bed. The maximum efficiency of corals on the idealized bed in mitigating the marine floods was with a wave period of 20 min (Fig. 5), but the efficiency was minimum for the same coral on the Gold Coast bed. This indicates that the relationship between the wave period and the bed slope is not simple like the wave height and bed slope when assessing the mitigation potential of coral reefs. Wave energy reduction is mainly determined by the effect of coral roughness and waves shoaling in this study. The roughness effect from corals is determined by water particle velocity (Eq. 3), which is a function of wave height and wave period. When the wave period increases, water particle velocity first increases and then decreases for the ideal bathymetry. However, this phenomenon is challenged by the shoaling effect of the Gold Coast bed due to its complexity. Therefore, we need experimental and field data to confirm the results. Table 2 shows the reduction in the force of the marine floods by the coral reef.

Table 2: Mitigation potential of the coral reef on the idealized and Gold Coast bed profiles (Fig. 1). H_b and T_p are the wave height and wave period at the generation boundary, respectively. Note that the force is calculated as the multiplication of the density of seawater, flow depth (= still sea depth + water surface elevation), and the square of water particle velocity (Nandasena *et al.*, 2008).

Force reduction behind the coral reef %						
	The roughness of corals (Manning's roughness coefficient n = 0.1)					
H_b (m)	Coral reef on the idealized bed			Coral reef on the Gold Coast bed		
	T_p = 10 min	T_p = 20 min	T_p = 40 min	T_p = 10 min	T_p = 20 min	T_p = 40 min
0.5	4	13	5	8	7	22
1.0	9	22	9	18	13	33
2.0	18	34	17	30	21	45
4.0	17	44	25	43	45	56
	The roughness of corals (Manning's roughness coefficient n = 0.25)					
H_b (m)	Coral reef on the idealized bed			Coral reef on the Gold Coast bed		
	T_p = 10 min	T_p = 20 min	T_p = 40 min	T_p = 10 min	T_p = 20 min	T_p = 40 min
0.5	22	51	25	38	35	63
1.0	39	66	40	61	51	75
2.0	59	78	56	76	66	83
4.0	77	85	69	91	82	88

The marine flood force is calculated as the multiplication of density of seawater, flow depth (= still sea depth + water surface elevation), and the square of water particle velocity (Nandasena *et al.*, 2008). When the wave height increased, the percentage reduction in the force increased. Regardless of the wave period, the percentage reduction in the force was greater than the reduction in wave height behind the reef. No significant difference in the reduction of the force was observed between the idealized and Gold Coast profiles. For the idealized bed, the maximum reduction of the force was achieved for the case with the waves of H_b = 4 m and T_p = 20 min, whereas for the Gold Coast bed, it was the case with waves of H_b = 4 m and T_p = 10 min.

4. Discussion

Coastal areas are subject to more frequent extreme flooding caused by tsunamis and big storms because of sea level rises due to global warming (Rovere *et al.*, 2017). Submarine barriers such as coral reefs can play a significant role to dissipate the flow of energy, thereby reducing potential damage to the coastline. The quantitative meta-analysis conducted by Ferrario *et al.* (2014) indicated that coral reefs in the Indian, Pacific and Atlantic Oceans dissipate 97% of the wave energy that would otherwise impact shorelines. Fernando *et al.* (2005) found a strong correlation between the water inundation and the extent of the coral and rock reef cover with a visible reduction in flow velocity when the tsunami approached the coral reef. Corals cause drastic wave attenuation (as much as 80%–95%) and act as submerged breakwaters (Lugo-Fernández *et al.*, 1994; Frihy *et al.*, 2004). This study also confirmed that the coral reef about 7.5 km long in the wave direction reduced the wave height to 65% and the wave force to 91% if the roughness of the reef was 0.25 s/m$^{1/3}$.

Inundation distance was largely determined by wave height and coastal topography; however, human modification of the reef did not contribute to the magnitude of damage on land (Baird *et al.*, 2005). In a numerical simulation, Kunkel *et al.* (2006) found that a sufficiently wide barrier reef within a metre or two of the surface reduces run-up on land by the order of 50%. They noted that the effectiveness depends on the amplitude and wavelength of the incident tsunami, as well as the geometry and health of the reef and the offshore distance of the reef. Both reflection and frictional dissipation are significant in reducing the energy transmitted over the reef. The broader and shallower the reef, the more protection it provides. This study shows that when the wave height increased, the percentage reduction in both wave height and wave force behind the reef increased. However, when the wave period increased, the reduction in wave height behind the reef first increased and then decreased for the reef on the idealized bed, and this was the opposite on the Gold Coast bed.

Many researchers have attempted to quantify the reef roughness by using numerical assessment and conducting field studies (Nunes and Pawlak, 2008). The rugosity index, the simple indicator for reef roughness, is calculated as $R_i = 1 - D_l/C_l$, where D_l is the direct tape length and C_l is the draped chain length over the reef (Fuad, 2010). A higher rugosity index represents greater coral roughness. Leon *et al.* (2015) explained the digital terrain model technique for surface roughness measurement, which involves using high spatial resolution photography of the reef surface, along with the Lidar and Global Positioning System data. A field study at John Brewer reef included measurement of reef-flat surface undulations and observation of non-linear oscillatory wave propagation over the reef flat. The study showed that the hydraulic reef roughness ranged between 0.04 m and 0.1 m. The flow resistance provided by the corals is due to their density and bonding with the platform (Massel, 2013). A study conducted by Lugo-Fernández *et al.* (1998) indicated that the wave attenuation characteristics for any reef depend on the reef morphology, such as reef geometry, coral alignments, and bottom friction. The reef morphology changes continually with extreme wave impacts, and therefore using a typical surface drag coefficient for all reefs would not be precise (Lugo-Fernández *et al.*, 1998). At scales of 1 m to 10 m, the most obvious physical feature of coral reefs is that they are remarkably rough, having bottom drag coefficients that are typically ten times larger (or more) than the typical value of 0.0025 found for muddy or sandy sea beds (Lugo-Fernández *et al.*, 1998). However, a numerical model study based on including the steady-state finite difference model indicated that the coefficient of friction (cf) for coral typically ranges between 0.05 m/sec and 0.4 m/sec, which correlates with Manning's roughness (n) of 0.1 s/m$^{1/3}$ and 0.25 s/m$^{1/3}$, respectively (Cialone *et al.*, 2008). In this study, we used the definition of Cialone *et al.* (2008). To the best of our knowledge, an accurate estimation of coral roughness in terms of flow–coral interaction (reef hydrodynamics) is not yet available. Therefore, large-scale experimental studies are needed to explore it.

Model simulation studies for the 2007 Solomon Islands earthquake showed that coral reef in the GBR region attenuated wave amplitude by at least 50% and delayed the tsunami arrival time at the shoreline by 15 min (Cummins, 2008). The roughness is important in determining the effect of the fringing reef on tsunami inundation, and based on sensitivity analysis, smooth reefs are more likely to increase the onshore velocity than rough reefs (Gelfenbaum *et al.*, 2011). The flow velocity impeded by the corals found its way to the land with greater intensity through low resistance paths created by anthropogenic coral removal, much the same way as water jetting through dead vegetation in wetlands (Granata *et al.*, 2001) and shorenormal gaps in coastal vegetation (Thuy *et al.*, 2009). Numerical simulation by Gelfenbaum *et al.* (2011) confirmed that healthy, rough coral reefs that are wide, high and without unnecessary channels offer the greatest protection from destructive tsunamis. In their experiment with a uniform array of rods, Fernando *et al.* (2008) simulated the gap effect in coral reefs. Coral reefs substantially decreased the flow velocity due to the increase in the bottom drag coefficient, which was a strong function of the coral porosity. Increased flow velocity through the gap was observed, which was a strong function of porosity, in addition to a suite of other parameters that accounts for waves, corals, water depth and gap size.

Gawehn *et al.* (2016) classified long-period waves into four different classes: resonant, standing, progressive-growing and progressive-dissipative waves. The results of their study indicated that wave resonance caused prolonged, large-amplitude water surface oscillations at the inner reef flat ranging in wave height from 0.14 m to 0.83 m. The waves had non-linear, bore-like wave shapes, which are likely to have a greater impact on the shoreline than regular, sinusoidal waveforms. We reported similar wave shapes at the reef (Fig. 3b); however, corals with high roughness of the Gold Coast bed profile can mitigate wave energy behind the reef by up to 88% with wave period. Reef shape to the characteristics of incident waves is an important factor controlling the hydrodynamic process over the reef platform surfaces (Mandlier and Kench, 2012). Elliptical and circular reefs could create distinctive wave convergence zones while linear platforms do not superimpose reef-flat waves. Our study also found that the mitigation potential of coral reefs is greatly controlled by the bed slope off the reef. Wave height reduction behind the reef was highest for the linear bed profile but lowest for the convex shape bed profile (Gold Coast profile) for the incident waves of 20 min.

The results of this numerical study confirmed that coral has an important role in marine flood reduction, and therefore protection of reef-building corals is important from an engineering perspective. Many researchers have realized the importance of corals and raised concerns regarding coral degeneration due to human developments and climate change. Government institutions and research centres are trying to control the adverse factors affecting coral degeneration and considering innovating and aspiring measures of forming artificial coral reefs by studying the behaviour of corals in a simulator environment. Further work is needed to address the issues of coral degeneration and the revival of reef morphology. Basic numerical and controlled experimental studies are pertinent for elucidating the rationales behind coral reef hydrodynamics that help to understand the mitigation potential of large coral reefs on a real scale.

5. Conclusions

The effect of roughness of coral reefs on mitigating marine floods caused by long-period waves was analysed using one-dimensional numerical simulations. The reduction in wave height and hydrodynamic force behind the coral reef were tested against the magnitude of marine floods subjected to the roughness of coral reefs. The reduction in wave height behind the reef and at the shoreline increases with the magnitude of the marine flood. The effect of wave period is not similar to the effect of wave height when assessing the mitigation potential of coral reefs on the sea bed. However, the marine floods caused by longer period waves can be slowed by higher coral roughness compared to the floods caused by shorter period waves. Despite the wave period, the reduction in wave force is greater than the reduction in wave height behind the reef. This study is limited in its scope and only provides long-wave behaviour over coral reefs for selective profiles and coral roughness in a one-dimensional numerical simulation. Further assessments are required to consider two-dimensional changes in bathymetry, wave breaking, and spatial change in coral roughness over the reef, non-uniformity of coral reef in sea depth, and wave hydrodynamics through the porous coral colonies.

Biographies

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Dr Nandasena, who is Sri Lankan, obtained a PhD in Civil and Environmental Engineering from Saitama University. He was a postdoctoral fellow of the Japan Society for the Promotion of Science. His research focus is high-energy coastal disasters, and he is known as a leading researcher in the field of boulder transport by tsunamis. He is a member of Inundation Signatures on Rocky Coastlines, National Science Foundation-funded Research Coordination Network, in the USA. He conducted field surveys in Japan after the 2011 Great East Japan tsunami.

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Mr Chawdhary, who is Indian, is a Senior Development Engineer at Auckland Council based in Auckland, New Zealand. He obtained a master's degree in Civil and Environmental Engineering from the University of Auckland. He is interested in the concept of ecosystem-based disaster risk reduction and testing the capability of coral reefs to mitigate high-energy wave events. He is also involved in various domestic and international projects on parks, transportation, water services, and other typical city government services. He is a member of the New Zealand (NZ) Coastal Society and Engineers NZ.

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