Measurements of time-averaged intensity of seawater motion with plaster balls at Polhena reef, Sri Lanka

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Abstract

Water motion is a critical environmental parameter especially for sessile marine fauna and flora. It is difficult to measure seawater motion with a propeller type of current meter in shallow coastal reefs. Therefore, we initiated a method to measure time-averaged intensity of water motion with plaster balls by placing them in the water column below the low tide level. Balls were made with plaster of Paris. A laboratory experiment was conducted on the relationship between of seawater flow and dissolution rate of plaster balls. This laboratory experiment revealed that 3.72 mg of the dry weight of the plaster balls were dissolved in seawater at a flow rate of 0.048 ms^{-1}. Using this relation, we calculated the average seawater motion at two reef locations ("off-shore" at the middle of the reef platform and "near-shore" at the edge of the reef platform) at Polhena reef by converting the loss of dry weight of plaster balls to the flaw rate of seawater. Though there was no any significant difference of mean time averaged intensity of seawater motion between two reef locations, off-shore location showed a higher time-averaged intensity of water motion (0.0233 ± 0.0004 SE) ms^{-1} than at the near-shore locations (0.0222 ± 0.0008) ms^{-1} (Two sample t-test; $T = 1.20$, $df = 4$, $P = 0.297$, $P > 0.05$). An understanding of water motion is essential to understand ecological adaptations of sessile marine fauna and flora. This method can be applied to obtain measurements of seawater motion even in slowly moving situations as it is simple and convenient.

Keywords:seawater motion, wave speed, plaster balls, coral reef, Polhena

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Introduction

Water motion is a critical parameter in marine environments, determining the distribution of sessile fauna and flora.Rate of water motion in the environment affects growth rate and distribution of marine organisms such as corals, phytoplankton and seaweeds (Thompson and Glenn, 1994). Measurement of seawater motion is challenging, because it is difficult to measure wave speed with a propeller type of current meter in shallow coastal reefs. There are sophisticated equipment (e.g. Electro-magnetic current meters) to detect wave speed, but they are very expensive, difficult to transport and use in shallow waters.Several methods for measuring time-averaged intensities of water motion have been devised. These include the increase in rust weight on iron plates in proportion to intensity of water motion (Matsudaira *et al.* 1967), dry weight loss of plaster balls (Muss 1968) and dry weight loss of plaster clods attached to plastic cards (Doty, 1971) those which placed on the sea bottom. There were difficulties in using rust accumulation as rate depends on oxygen content of the seawater (Komatsu and Kawai, 1992). In addition, all other methods by Muus (1968) and Doty (1971) were to estimate intensities of water motion only at the sea bottom not in the water column. The aims of this study were to, 1) develop a method to measure time-averaged intensity of water motion with plaster balls by setting them in the water column below the low tide level and 2) compare time-averaged water motion at two reef locations ("off-shore" at the middle of the reef platform and "near-shore" at the edge of the reef platform towards the shore) at Polhena reef.

Materials and methods

Site selection: The current study was conducted on Polhena reef situated in the southern coastal region of Sri Lanka and two reef locations were selected as "off-shore" at the middle of the reef platform and "near-shore" at the edge of the reef platform towards the shore.

Preparation of plaster balls: Plaster of Paris was mixed with water and poured into plastic balls (mould). They were allowed to solidify. Plaster balls were dried in an oven in 105^0C to a constant weight and the initial values were recorded.

Laboratory experiment: A laboratory set-up was used to calculate the weight loss of plaster balls exposed to a known speed of seawater motion. A plaster balls with known weights were placed in a container in a practical set-up and seawater with known speed (0.0482 ms^{-1}) was allowed to move through the container for 60 seconds and it was repeated for another 2 plaster balls separately. Finally, the loss of averaged dry weight (0.0037 gs^{-1}) of those plaster balls were calculated. That value was use to calculate the seawater motion in real marine environment, considering the average weight loss of plaster balls installed in-situ.

Field installation of plaster balls: Six plaster balls were fixed in the reef at each location. Two nylon ropes were attached to each ball. One rope was attached to the reef, while a buoy was attached to the other rope keeping the plaster ball suspended in the water column. They were allowed to dissolve for 6 hours. They were collected and carefully transported to the laboratory. Weight loss of plaster balls were measured after drying those balls to a constant weight using a drying oven (nearly 24 hours). Calculations were done to obtain time-averaged seawater motions at two locations of the reef. The field studies were conducted on November 23, 2015.

Our assumptions: 1) There is unique dissolution over the entire surface of plaster balls, 2) There is unique dissolution rate over the given time and mass losses of balls are directly proportional to flow rate, 3) The shape of the plaster ball (ball shape) does not affect for dissolution rate and 4) There were no any water quality changes (salinity, turbidity, pH.etc) during the study period.

Results

Laboratory experiment revealed that the mean weight loss of plaster balls was 3.72 mgs^{-1} with 0.0482 ms^{-1} seawater speed. Time-averaged seawater motion was calculated by dissolution of plaster balls which were placed at off-shore and near-shore locations of Polhena reef by using above data. There was higher time-averaged intensity of seawater motion (0.0233 ± 0.0004 SE) ms^{-1} at off-shore location than at near-shore locations (0.0222 ± 0.0008) ms^{-1}. However the difference was not significant (Two sample t-test; $T = 1.20$, $DF = 4$, $P = 0.297$, $P > 0.05$).

Discussion

The mean time-averaged water motion at Polhena reef was 0.0227 ms^{-1}. There was comparatively higher time-averaged water motion at off-shore location (0.0233) than the near-shore location (0.0222). Differences in water motion may contribute to the distribution pattern of benthic organisms at this reef. High speed of waves can break the branching corals thus promoting other growth types such as encrusting corals. Senarathna *et al.* (2013) found that encrusting *Montipora* species dominated at off-shore locations, while the branching Pocilloporids were more abundant at near-shore locations. That may be because higher velocity may result in breakages of branching corals at off-shore locations, thus encrusting *Montipora* species may abundant at that location. Therefore water motion is an important parameter to be concerned in ecological studies in coral reefs.

Table 1. Calculation of time-averaged seawater motion at two reef locations at Polhena reef.

Time (s)	Mean dissolution rate of plaster ball (mgs^{-1})		Mean seawater motion (ms^{-1})	
	Off-shore	**Near-shore**	**Off-shore**	**Near-shore**
60 *60*6	1.796	1.716	0.0233	0.0222

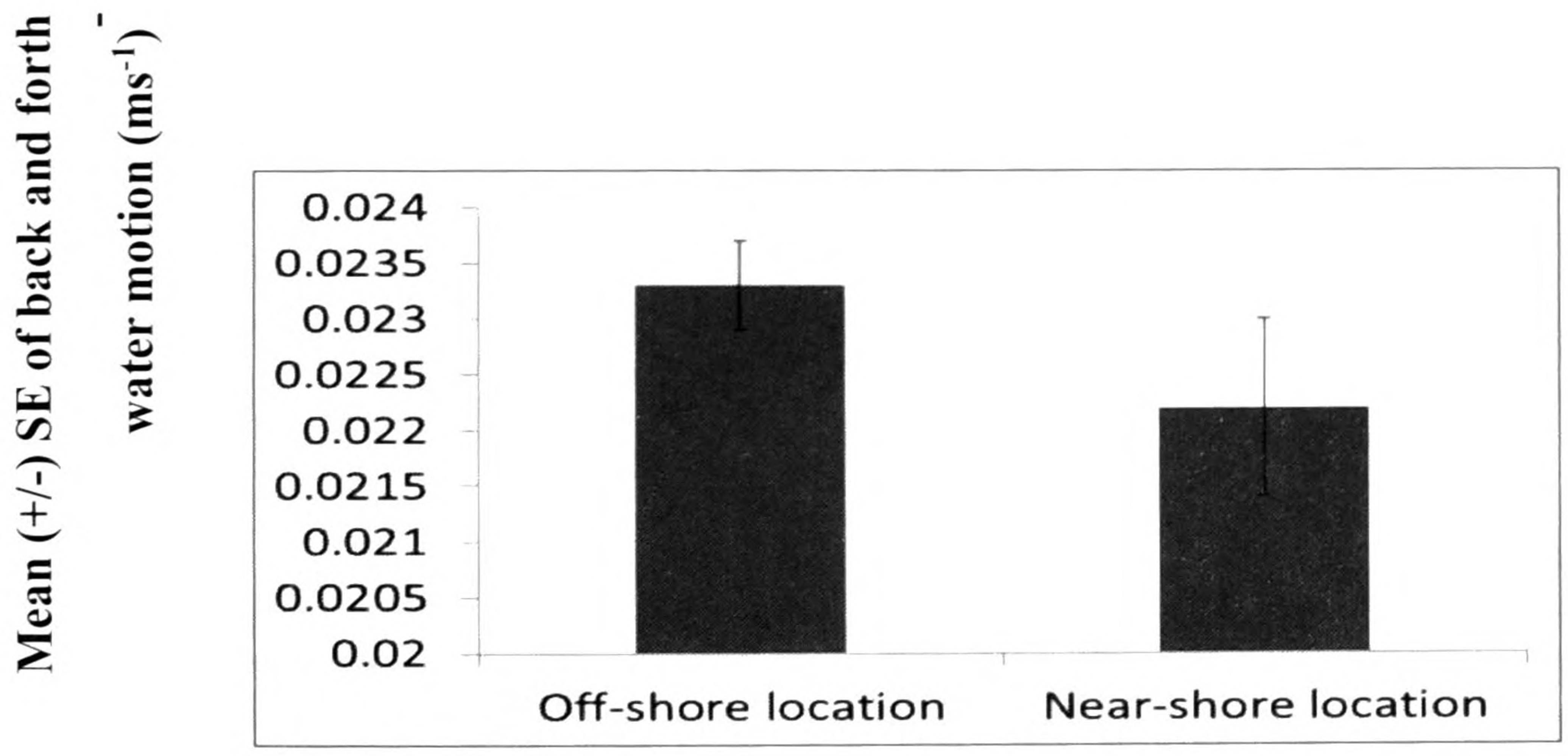

Fig 1: Time averaged intensity of water motion (ms^{-1}) at off-shore and near-shore locations of Polhena reef

There were research limitations and improvement of this study in future. Numbers of replicates have to increase with the extended time periods to monitor the dissolution of plaster ball throughout a day (24 hours) and compare with water quality parameters. Studies have to focus onwet weight than dry weight as it is convenient. A laboratory experiment has to examine whether the dissolution rate change with the reduction of the size of plaster ball, and it will be easy to conduct this experiment when using the wet weight. A more robust ball holding unit has to be developed rather than using two ropes to keep the ball in water column.

Conclusion

Use of plaster balls to determine seawater motions at shallower reef is a cheap and convenient method. This study found that the mean time-averaged intensity of seawater motion at Polhena reef was 0.0227 ms^{-1} and it was changed from place to place. Off-shore locations exhibited comparatively higher water motions than the near-shore locations. Water motions might impact on the type of existing sessile fauna at different locations of the reef.

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