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Assessing the Impact of Sand Dredging Along the Coastal Waters of Fuailoloo Village, Samoa

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ABSTRACT

Local dredging activities have led to increase water turbidity and deleterious impacts on nearby marine invertebrates. These are some of the major issues faced by the Fuailoloo Village which has hindered the progress in managing the reserve and at the same time has caused stress on the marine resources, resulting in the poor growth of marine species being spawned within the reserve. The main purpose of this research study was to perform a rapid impact assessment of the impacts of local sand dredging and water pollution from nutrients and chemicals from the wharf have on the newly proposed marine protected area. Surface water samples were collected monthly outside and inside the marine protected area and near the dredging sites. The concentration of nutrients detected were in the ranges of 0.16-3.98 mg/L (nitrate), 0.08-3.21 mg/L (phosphorus) and the chemicals were 0.01-0.07 mg/L (Fe), 0.23-2.63 mg/L (Cu) and 0.25-0.48 mg/L (Pb) respectively. In Samoa, the information on the ecotoxicological impact of sand dredging is limited. This study will be used as a baseline assessment to measure further monitoring against over the lifetime of the Marine Protected Area (MPA) and will also be used in the development of recommendations to mitigate environmental impacts from local disturbances.

INTRODUCTION

Sea sand become a very important mineral for the expansion of the society in terms of size and in protecting the environment, buffer against strong tidal waves and storm, habitat for crustacean species and marine organisms (Saliu *et al.*, 2013). Dredging is a necessary activity in civilisation's development. In its simplest form dredging consists of the excavation of material from a sea, river or lake bed and the relocation of the excavated material elsewhere Central Dredging Association (CEDA, 2009). It is commonly used to improve the navigable depths in ports, harbours and shipping channels, as a tool in water and flood management, creation of new lands and natural habitats, or to win minerals from underwater deposits. Dredging is therefore of crucial importance for sustainable development of nature resources, economic values and human quality of life. Sea sand become a very important mineral for the expansion of the society in terms of size and in protecting the environment, buffer against strong tidal waves and storm, habitat for crustacean species and marine organisms (Chen *et al.*, 2014). Dredging is a necessary activity in civilisation's development. In its simplest form dredging consists of the excavation of material from a sea, river or lake bed and the relocation of the excavated material elsewhere (Pekey, 2006). It is commonly used to improve the navigable depths in ports, harbours and shipping channels, as a tool in water and flood management, creation of new lands and natural habitats, or to win minerals from underwater deposits. Dredging is therefore of crucial importance for sustainable development of nature resources, economic values and human quality of life. Local dredging activities have led to increase water turbidity and deleterious impacts on nearby marine invertebrates. These are some of the major issues faced by the Mulifanua Village which has hindered the progress in managing the reserve and at the same time has caused stress on the marine resources, resulting in the poor growth of marine species being spawned within the reserve. It has also impacted the village community because most families very much rely on coastal marine resources for their subsistence livelihood. The main purpose of this research study is to perform a rapid impact assessment of the impacts of local sand dredging and water pollution from nutrients and chemicals from the wharf have on the newly proposed MPA. This study will be used as a baseline assessment to develop monitoring strategies over the lifetime of the MPA and will also be used in the development of recommendations to mitigate environmental impacts from local disturbances. The focus of this study will be aligned with two strategic priorities under Environmental Sustainability, one of the four key priority areas in the Strategy for the Development of Samoa (SDS) 2012 – 2016 (Ministry of

Finance, 2012): "*Support scientific research and data collection for better management* and *Effective assessment and monitoring of water resources"*. Additionally, it will be aligned with the Strategic Priorities on Marine Resources – *to create secure and effective MPAs and reduce pressures on coastal habitat and species* (Ministry of Natural Resources and Environment, 2014). The objectives of this study are to (i) assess the effects of resuspended sediments due to dredging operations and (ii) study the seasonal variation with respect to the physicochemical parameters of surface and bottom water and sediment samples.

METHODS

Study Site

To assess the impact of dredging, the surface water and sediment samples were collected monthly outside and inside the Fuailoloo-Mulifanua MPA and near the dredging site (13.8°S, 172.02°W) (Fig.1.) for a period of twelve months from November 2016 to October 2017.

Fig 1: Satellite image of Fuailoloo's MPA

Sampling Preparation

Preservation and transportation of the samples were as per standard methods (APHA, 1998). The water temperature was measured on the site. Surface water samples were collected using a water sampler; the sediment samples (3-5 cm) were collected and placed in a polyethylene plastic bag and kept in an ice box. Sediment samples were oven dried to a constant dry weight at 80ºC and sieved through a 63 µm stainless steel sieve (Table 1).

Table 1. Sampling sites with distance from MPA and Sampling Depth.

Sites	Distance from MPA (m)	Distance from Dredging site (m)	Depth (m)
MPA161	50	50	0.2
MPA162	100	100	0.4
MPA163	150	150	0.6
DS164	200	200	0.8
DS165	250	250	1.0
DS166	300	300	1.2

Chemical Analysis

About 0.5 g of dried homogenised sample was placed in a 50 mL Digitube. The <65 μm fraction was used for the evaluation of sediment physicochemical parameters namely pH, conductivity, organic matter and bicarbonates of calcium. Sediment's pH was measured in a suspension of 25 mL de-ionized water to 5 g of sediment after shaking for 2 hrs. Conductivity was evaluated from the suspension prepared by adding 50 mL de-ionized water to 5 g of sediment and shaken for 30 min. The Total Suspended Solids (TSS) were determined using the filtration method. Turbidity was measured by the HI9829 Multiparameter waterproof meter. The blank samples were all prepared in duplicates by adding 2 mL of deionized water to each tube. The spiked samples were prepared by adding 200 μL of 500 mg/L trace metals Intermediate Standards (contains Fe, Mn, Cu, Cd, Pb, Zn) to a sample replicate. A 2.5 mL of concentrated nitric acid was added to each digestion vessel and left overnight to pre-digest. The samples were placed in the digestion block and heated to 80°C for 60 minutes. Samples were again left overnight to settle out any solid material. The resultant mixture was made up to 50 mL with distilled water. Heavy metal (Cu, Pb) analysis was achieved by flame Atomic Absorption Spectrometry (AAS).

Statistical Analysis

One-way ANOVA and T-tests were used to evaluate the significant difference in the concentration of different study sites. A probability at level 0.05 or less was considered significant. Standard errors were also estimated.

RESULTS & DISCUSSION

Dredging and disposal processes cause temporary increase in the levels of organic matter and nutrients available to marine life. The release of organic rich sediments during dredging or disposal can result in the localised removal of oxygen from the surrounding water. Depending on the location and timing of the dredge this may lead to the suffocation of marine animals and plants within the localised area or may deter migratory fish or mammals from passing through. From the analysis result, the temperature of the samples ranges from 27.1°C to 28.9°C and the pH values ranges from 5.43 to 6.01. This shows that the dredging site and near the MPA environment is cool and conducive for marine organisms. The value of the F ranges from 60 mg/L to 518 mg/L and the turbidity of the seawater samples ranges from 45 mg/L to 181 mg/L. When dredging of sand materials in coastal water occur, it eventually suspends the fine sediments and increases the water turbidity. It was observed that the turbidity was usually higher near the dredging site for both surface and bottom water in comparison to the MPA. This may be due to dredging as well as also due to higher current and tidal action which cause resuspension of sediments (Abdallah, 2007; Abubaker *et al*., 2011). In addition, resuspension of sediments or sand resulted in an increase of the levels of organic matter and nutrients (such as nitrate and phosphorus) available to marine organisms. Runoffs from residential area and rivers are the main sources of nutrients in the estuarine regions besides dredging (Balachandran *et al*., 2005; Mohammad *et al.,* 2013).This study revealed that nitrate (NO_3^-) values ranges from 0.9 mg/L to 5.76 mg/L and Phosphorus (P) values ranges 0.01 mg/L to 0.11 mg/L. The values of nitrate and phosphorus in the surface waters were higher near the dredging sites in comparison to the MPA. Release of domestic wastes and use of nitrogenous fertilizers in the coastal area could also be the plausible reason for these values. The values for some heavy metals ranged from 0.01 mg/L to 0.03 mg/L for Fe, 0.03 mg/L to 0.60 mg/L for Cu and 0.194 mg/L to 0.249 mg/L for Pb. Leaching of heavy metals from boats and ships coated with antifouling paints, resulted in potential toxic concentrations in the water column, sediments and tissues of marine organisms have been documented in developed countries Concentrations were especially high in areas of high shipping or boating activity and very serious biological impacts were inevitable in the most contaminated areas (Neto *et al*., 2000; Imo *et al.,* 2014). The release of heavy metals from sediments may not only result from re-suspension of particulate matters, but also through the activities of micro-organisms within the sediments and at sediment-water interface, resulting in bio-transformation to more volatile or soluble forms (Sheikh *et al.,* 2007; Sangita *et al.,* 2014). Metal concentrations from the sampling locations were compared with values reported from different regions of the world (Table 2) and the levels were comparable to concentration detected in sediments from the different regions of the world.

Table 2. Heavy metal concentration (mg/g) in the sediment from the different regions of the world

Rivers/Ports	Cu	Pb	Reference
Mulifanua wharf, Samoa	0.97-3.82	1.23-2.82	Imo, *et al*. (2014)
Cochin estuary, India	53.15	71.28	Balachandran *et al.* (2005)
Jurujuba sound, Brazil	51.0	61.0	Baptista Neto *et al.* (2000)
Tolo harbour, Hong Kong	84.0	144.0	Owen and Sandhu, (2000)
Izmit Bay, Turkey	67.6	102.0	Pekey (2006)
Koahsiung Harbour, Taiwan	5-946	9.5-470	Chen *et al.* (2004)
Eastern Harbour, Egypt	14.09	-	Abdallah and Abdallah (2007)
River Ganga, India	0.09	-	Singh *et al.* (2012)
Mudflat of Salinas de San Pedro Lagoon, California, USA	0.085 - 0.47	0.05 - 0.38	Mohammad H.R *et al.* (2013)

Samples collected from the Mulifanua wharf revealed significantly higher levels of copper and lead than the samples collected at the fishing port. This could be due to the increased traffic of ferries between the two islands as most businesses and locals equipped for the festive seasons towards the end of the year. Metal concentrations from the sampling locations were compared with values reported from different regions of the world (Table 2) and the levels were comparable to concentration detected in sediments from the different regions of the world. Sediments may play a considerable role in the remobilization of trace metals from bottom sediments into the water body under suitable conditions and consequently, fish ingestions and bio-accumulations. The release of heavy metals from sediments may not only result from re-suspension of particulate matters, but also through the activities of micro-organisms within the sediments and at sediment-water interface, resulting in bio-transformation to more volatile or soluble forms.

Heavy metals in sediments

The sediments collected at the Mulifanua wharf shows an insignificant variation in pH values that range from 6.79 – 8.54. Conductivity (EC) shows higher values in all samples. This increase in conductivity may be attributed to the high content of soluble salts in sediments (Saviour, 2012; Singh & Singh., 2012). The relatively high content of TOM is mainly related to the high organic matter flux to sediments due to direct runoff from anthropogenic activities. In the commercial port, the concentration of heavy metals in August ranged from

[1.01-3.59 mg/g (Cu)], [1.23-2.56 mg/g (Pb)], September [1.01-3.71 mg/g (Cu)], [1.32-2.73 mg/g (Pb)] and October [1.10-3.82 mg/g (Cu)], [1.32-2.82 mg/g (Pb)]. The highest concentration of Cu and Pb was found at sites DS165 and DS166 respectively. The mean concentration of metals from the samples collected at the commercial port is in the order of Pb>Cu. Mulifanua wharf is the closest wharf and convenient for commuters between Upolu and Savaii Island, thus the increased traffic of ferries daily. The heavy metals detected in the Mulifanua wharf indicated that the boating activities contributed a significant amount of Pb and Cu into sediments.

CONCLUSION

In Samoa, the information on the ecotoxicological impact of heavy metals, nutrients and other pollutants on sediments are limited. This research examined environmental impacts of sand dredging near the newly MPA at Fuailoloo, Mulifanua. The research was conducted through data collection and physical observation of the study area. Certain values of turbidity, total suspended solids, nutrients and some heavy metals were observed near the MPA and the dredging site. The results obtained from this study advocate for further studies regarding emerging threats of dredging and anthropogenic activities on the vital marine resources which have significant importance to the livelihood of coastal societies, particularly the Fuailoloo village, Mulifanua. The sediments recorded high levels of heavy metals (Cu, Pb) in all sampling locations within the sampling months which could be due to boating activities. Great efforts and cooperation between different authorities are needed to protect the coastal and coral reef ecosystems from pollution and reduce environmental risk. This can be achieved by treatment of the residential and sewage discharge. Regular evaluation of pollutants in the coastal and coral reef ecosystems is also very important. The results obtained from this study advocate for further studies regarding emerging threats of heavy metals on the vital marine resources which have significant importance to the livelihood of coastal societies, particularly Small Island States including Samoa.

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