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Studies of nutrient variability and the consequences for benthic communities on the Coral Coast fringing reefs, Fiji

Ulukalesi B. Tamata
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**STUDIES OF NUTRIENT VARIABILITY AND THE CONSEQUENCES
FOR BENTHIC COMMUNITIES ON THE CORAL COAST
FRINGING REEFS, FIJI**

A thesis submitted in fulfillment of the requirements for the award of the degree

DOCTOR OF PHILOSOPHY

from

UNIVERSITY OF WOLLONGONG

by

ULUKALESI BALE TAMATA
(BSC, MENVSTUDIES)

SCHOOL OF EARTH AND ENVIRONMENTAL SCIENCES

Thesis Certification

I, Ulukalesi Bale Tamata, declare that this thesis, submitted in fulfillment of the requirements for the award of Doctor of Philosophy, in the School of Earth and Environmental Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.



Ulukalesi Bale Tamata

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LIST OF ACRONYMS

AIMS	Australian Institute of Marine Science
ANOVA	Analysis of variance
ANZECC	Australian and New Zealand Environment and Conservation Council
CCC	Coral Cay Conservation
COTS	Crown-of-thorns starfish
CSM	coral surface microlayer
EEZ	Economic Exclusive Zones
EHMP	Ecosystem Health Monitoring Program
FVB	Fiji Visitors Bureau
FLMMA	Fiji Locally Managed Marine Areas Network
GAR	Great Astrolabe Reef Lagoon of Kadavu, Fiji
GBR	Great Barrier Reef of Australia
GCRMN	Global Coral Reef Monitoring Network
GDP	Gross Domestic Product
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environment Protection
IAS	Institute of Applied Sciences
ICLARM	International Center for Living and Aquatic Resources Management
ICM	Integrated Coastal Management
ICRI	International Coral Reef Initiative
IDA	Inside Demarcated Areas
IOC	International Oceanographic Commission
IOI	International Ocean Institute
IUCN	International Union for Conservation of Nature and Natural Resources
LNSW	Low nutrient seawater
MPA	Marine Protected Area
RDM	Relative Dominance Model
SEAKEYS	The Sustained Ecological Research Related to the Management of the Florida Keys Seascape
SIDS	Small Island Developing States
SOPAC	Pacific Islands Applied Geoscience Commission
SPREP	South Pacific Regional Environment Program
USP	University of the South Pacific
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Program
WFD	Water Framework Directive

LIST OF NON-ENGLISH (FIJIAN) WORDS

Cawaki	Sea urchin harvested by locals for subsistence or commercial use
Dabi	<i>Xylocarpus granatum</i> , a coastal plant with medicinal uses
Dogo	<i>Bruguiera gymnorhiza</i> , a coastal mangal species
I Qoliqoli	Traditional fishing grounds for indigenous Fijians
Kuka	<i>Sesarma erythrodactyla</i> , red-clawed mangrove crab harvested for subsistence and commercial use by locals
Qari	<i>Scylla serata</i> , mud crab harvested for subsistence and commercial use by locals
Sinugaga	<i>Xecocaria agallocha</i> , a coastal mangal species
Tabu	MPA, 'no-take' zone
Tiri	<i>Rhizophora stylosa</i> , a mangrove species
Tiritabua	<i>Rhizophora mucronata</i> , a mangrove species
Tiriwai	<i>Rhizophora mangle</i> , a mangrove species

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Abstract

The Coral Coast region, in south-western Viti Levu, Fiji, is the ‘hub’ of tourism development in Fiji, and is one of the fastest developing areas in Fiji. Since the 1980s, development along the Coral Coast has occurred at a rate never previously seen in this area. Large resorts and smaller backpacker facilities emerged from the once coconut-tree lined coastal stretch, from Serua, to Natadola. Village populations have also increased. Anecdotal information and the few, sporadic studies conducted in this area have indicated that the water quality and the biological communities on the fringing reefs have deteriorated dramatically since the 1980s. Live corals which used to feature prominently on the fringing reefs (hence the name ‘Coral Coast), have been replaced by weedy macroalgae, the most common of which is the brown algae *Sargassum*. The Coral Coast fringing reefs were apparently undergoing phase shifts (like other reefs around the world), and anthropogenic factors have been blamed. The need for scientific information on the effects of anthropogenic activities on the Coral Coast water quality and fringing reef communities prompted this study.

The study had several objectives. Two major components addressed the need to establish baseline scientific information on the variability of dissolved nutrients in the water column, and the status of biological communities on the reef flats of the fringing reefs, for control sites (away from human impacts), and impacted sites (close to villages and resorts). Nutrients from anthropogenic sources on land have been identified as one the major bottom-up controlling factors for phase shifts on coral reefs. Control, village and resort sites were monitored for nutrient concentrations from 2003 – 2006, and sampling times covered seasonal as well as weather effects, particularly the effects of storm-associated rainfall. Benthic surveys were also carried out in control and impacted sites several times over the period 2004 – 2006. To complement the results from the longer term monitoring of water quality and reef benthic communities, a number of short-term, targeted experiments were conducted in the laboratory and in the field, to examine nutrient uptake by algae, herbivory impacts and nutrient sources.

A combination of the Line Transect and Quadrat Point Intercept methods were used for the assessment of the abundances and distribution of the main species on the fringing reefs, especially *Sargassum* sp. Nutrient enrichment experiments were conducted in the laboratory and also in the field to assess uptake of nutrients by *Sargassum* sp. Herbivore-exclusion caging experiments were conducted in the field to assess influence of herbivory in a 'tabu' or marine protected area (MPA) as well, as in non-'tabu' or open-fishing sites. Samples of *Sargassum* sp. and a few other dominant macroalgae species from the study sites were analysed for tissue nitrogen and phosphorus contents and for $\delta^{15}\text{N}$ content, to aid nutrient source identification.

Nutrient concentrations were highly variable, showed little association with season, but were strongly linked to rainfall. The results indicated the clear influence of pulse (storm runoff related) events on the nutrient concentrations in the water column. Control sites generally recorded lower nutrient concentrations than impacted sites, confirming the anthropogenic effects on water column nutrients. The biological communities on the fringing reefs reflected the status of nutrients in the water column, i.e., reefs close to human impacts recorded higher abundances of macroalgae, especially *Sargassum* sp., and lower abundances of live corals. The nutrient enrichment experiments showed the ability of *Sargassum* sp. to take up nutrients very quickly from the water column, but the rhizoids showed greater responses than the leafy shoots used in the experiments. The 'low growth' season for *Sargassum* sp. during the Cool season (May to October) may be the explanation for the differential responses between the rhizoids, and the leafy parts of the *Sargassum* plants used in the experiment. Caging experiments showed the significance of herbivory in the control of *Sargassum* sp., and the 'tabu' sites appeared to show a greater intensity of herbivory (lower survivorship for uncaged shoots). Both tissue nutrient and $\delta^{15}\text{N}$ contents in macroalgae samples matched the findings from the water column nutrient studies, i.e., the human-impacted sites exhibited nutrient enrichment in the water column and in the macroalgae on the reef flats. *Sargassum* samples from impacted sites had higher tissue % N and higher $\delta^{15}\text{N}$ contents compared to the control sites confirming that human activities were enriching the coastal waters with nutrients.

On the basis of the results from this research, recommendations are proposed for better management of nutrient sources on land for the protection of the water quality, and therefore promote healthier coral reef systems. The significance of protecting herbivorous species is also important, and the setting aside of 'tabu' sites is encouraged. Areas of further research are also identified, for better understanding of the interrelationships among all the factors involved in the phase shift occurring on the fringing reefs along the Coral Coast of south-western Viti Levu, Fiji.

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