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CARACTERIZAÇÃO DA COMUNIDADE EPIBENTÔNICA EM RECIFES DE CORAIS DAS ILHAS FIJI POR VÍDEO-IMAGEM

Trabalho de Conclusão de Curso submetido à Universidade Federal de Santa Catarina como parte dos requisitos necessários para obtenção do Grau de Bacharelado em Ciências Biológicas.

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CARACTERIZAÇÃO DA COMUNIDADE EPIBENTÔNICA EM RECIFES DE CORAIS DAS ILHAS FIJI POR VÍDEO-IMAGEM

Por

Camila Rezende Ayroza

Trabalho de Conclusão de Curso julgado adequado para a obtenção do título de "Bacharela em Ciências Biológicas" e aprovado em sua forma final pelo Programa do Curso de Ciências Biológicas.

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Ao mar...
quem nos ensina que
há dias de tormenta
e calmaria.
Que dentro dele
é também como dentro de nós:
belo, misterioso, infinito
e incompreensível.
O que me faz
eternamente buscar...

AGRADECIMENTOS

Primeiramente...

Gostaria de agradecer ao governo (legítimo) que através do Programa Ciências Sem Fronteiras obtive uma das maiores oportunidades da minha vida, o qual sem ele este trabalho não existiria. Por poder ter tido a experiência que tive durante o período de intercâmbio, o qual não somente me enriqueci profissionalmente, mas também como pessoa e cidadã, que vê ainda mais alternativas e continua tendo esperança nas possibilidades de poder se construir diferente. Pude ampliar minhas visões de mundo, e hoje quero lutar para transformar a educação, a universidade, o governo e a própria ciência.

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Gratidão!

RESUMO

A profundidade é um dos indicadores mais bem estabelecidos para o estudo da distribuição de comunidades bentônicas nos ecossistemas marinhos por estar diretamente relacionada com a zona fótica disponível. Todavia, a maioria dos estudos analisa ambientes recifais até 30 metros dado o limite do SCUBA. Consequentemente, sabemos pouco sobre estrutura de comunidades ao longo de um gradiente de profundidade entre os recifes rasos e mesofóticos. Os veículos automatizados são exemplos de tecnologias disponíveis para investigação de recifes em ambientes mais profundos. No entanto, são necessárias adequações das metodologias operacionais e amostrais para a coleta dos dados A alta quantidade de dados gerada precisa ser otimizada. Os dados podem ser integrados com resultados de outras pesquisas para ampliação do conhecimento dos processos ecológicos. Esquemas metodológicos de identificação de organismos bentônicos em imagens subaquáticas vêm sendo desenvolvidos a fim de poderem ser adaptados globalmente. O CATAMI (*Collaborative and Automated Tools for Analysis of Marine Imagery*) é um exemplo disso, que propõe um esquema com uma abordagem morfofuncional taxonômica hierárquica. Neste estudo utilizou-se veículos remotamente operados (*ROV's)* e adotou-se a classificação hierárquica baseada no CATAMI. Modelos de distribuição de espécies foram utilizados para avaliar o efeito da profundidade na composição de comunidades bentônicas de 10 à 130 metros, em recifes de corais na área de *Vatu-i-Ra*, ilhas Fiji. Observou-se que a profundidade foi significantemente relacionada com a presença e abundância de três dos quatro grupos epibêntonicos investigados. A abundância de corais pétreos diminuiu com a profundidade, enquanto a abundância de corais negros, octocorais e macroalgas aumentou até os 50 metros, e então diminuiu significantemente nas profundidades subsequentes. Esponjas e ascídias foram relativamente abundantes (>30%) ao longo de toda profundidade investigada, assim como o grupo de macroalgas (>40%). Este estudo demonstra que imagens originadas de ROVs podem ser utilizadas para caracterizar a composição da comunidade epibentônica ao longo de uma ampla escala de profundidade, e assim contribui para nosso conhecimento sobre recifes de corais mesofóticos.

Palavras chave: Comunidades bentônicas. Mar de Coral. Gradiente de profundidade. Vídeo-imagem.

ABSTRACT

Depth is a well established surrogate of benthic species distribution in marine ecosystems, because it is directly related to the available photic zone. However, most studies focused on reefs shallower than 30 meters due to the SCUBA limits. Therefore, we know little about community structure across depth gradient from shallow to mesophotic reefs. Automated vehicles are examples of available technologies for deeper reefs studies. Amongst novel technologies, there is a need for methodologies adequacy to not only operational protocols, but also to data sampling. The large amount of generated data need also be compiled. This data could be integrate with others researches results to increase our knowledge of ecological processes. Methodological classification schemes of benthic biota identification in marine imagery have been developed to be adapted globally. As an example of CATAMI (*Collaborative and Automated Tools for Analysis of Marine Imagery*) that combines a coarse-level taxonomy and morphology approach with a hierarchical classification scheme. Here we used remotely operate vehicle, and we adopt a hierarchical classification based on CATAMI. Species distribution models were used to assess the effect of depth on the epibenthic community composition from 10 to 130 meters depth, in coral reefs of Vatu-i-Ra seascape, Fiji. Depth was significantly related to the presence and abundance of three out of four epibenthic groups. Stony coral abundance decreased with depth, while octocorals and macroalgae increased with depth up to 40 – 50 m and then significantly decreased below these depths. Other invertebrates, such as sponges and ascidians, were relatively abundant (>30%) across all depths, as well the taxa macroalgae. This study demonstrates how imagery from remotely operated vehicles can be used to characterize the benthic community composition across a broad depth gradient and advances our knowledge of the function of mesophotic coral reefs. It is one in a handful of studies that describes the entire epibenthic community composition beyond 30 meters depth.

Key words: Benthic communities. Coral Sea. Depth spanning. Underwater imagery.

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INTRODUÇÃO GERAL

Recifes de corais são os sistemas marinhos mais biodiversos e economicamente importantes, promovendo serviços ecológicos, como o turismo, proteção de linha de costa e mangues, pesca, além de valores estéticos e culturais (Bellwood et al. 2004; Hoegh-Guldberg, et al. 2007). No entanto, esses sistemas estão altamente ameaçados sofrendo um processo contínuo de deterioração principalmente por atividades antropogênicas, diretas e indiretas, em escala global e local, tais como sobrepesca, mineração, urbanização costeira, acidificação oceânica, “blooms” de algas , aumento da incidência de doenças e colonização de espécies invasoras (Hughes et al. 2003; Mumby and Steneck, 2008; Graham, et al. 2014).

Ecossistemas de recifes de corais mesofóticos (MCE’s - Mesophotic Coral Ecosystem) são caracterizados por comunidades de corais zooxantelados que se iniciam nos 30-40m de profundidade – correspondente às profundidades limites do tradicional SCUBA - até a profundidade limite da zona fótica, variando de acordo com a região e a suspensão de partículas, consequentemente com a entrada de luminosidade (Pyle 2008; Kahng and Wagner 2013). Esses sistemas apresentam uma extensão direta dos recifes rasos, suportando uma diversa abundância de organismos construtores de habitats, como corais, esponjas e algas (Kahng et al. 2010; Hinderstein et al. 2010) sendo considerados por Blyth-Skyrme et al. (2013) e Kahng and Wagner (2013), como locais menos vulneráveis a pressões antropogênicas, tormentas e branqueamento. Também são reportados como ‘*deep-reef refugia*’, ou seja, como locais para refúgio e fonte para recuperação de assentamento de larvas de diversos taxa (Lesser et al. 2009; Bongaerts et al. 2011; Loya et al. 2016). Apesar da relevância ecológica dos MCE’s, a vasta maioria dos estudos de recifes de corais são conduzidos somente em recifes de habitats rasos (< 30 m), pela maior acessibilidade desse ecossistema. Portanto, existe uma lacuna crítica no conhecimento de MCE’s e por consequência, gerando pouco subsídios para sua conservação (Lesser et al. 2009; Kahng et al. 2010; Bridge et al. 2011).

Rossi (2013) levanta a questão da falta de adequado manejo marinho e da tendência devastadora da nossa sociedade perante esse ecossistema. Nesse sentido, a falta de um patamar de referência sobre como os ecossistemas bentônicos funcionam, a estrutura da comunidade e suas interações com outros organismos e fatores abióticos são apontados como o principal problema para a falta desses estudos de base. Essa deficiência de informações dificulta a avaliação de como esses sistemas irão se comportar no futuro e da concepção estratégica para protegê-los (Jackson 1997; Bridge et al. 2011).

Nesse contexto, frente aos recentes progressos tecnológicos, encontra-se uma oportunidade única de explorar profundidades desconhecidas e cobrir grandes áreas geográficas para novos campos de investigação dos ecossistemas marinhos (Mumby et al. 2004). Dentro das tecnologias disponíveis estão inclusas a utilização de misturas gasosas para mergulhos profundos (Pyle 2000) e o desenvolvimento da imagem óptica de veículos autônomos subaquáticos (AUV's - Autonomous Underwater Vehicle) e veículos remotamente operados (ROV's – Remotely Operated Vehicle) visando temas específicos relacionados à biodiversidade, lidando com mapeamento de habitats e cobertura bentônica em múltiplas escalas (Bridge et al. 2012; González-Rivero et al. 2016). Esses últimos estão sendo cada vez mais utilizados em todo o mundo, como, por exemplo, nos programas de monitoramento e pesquisa marinha da Austrália, Alasca, Estados Unidos, Nova Zelândia e países da Ásia (Bridge et al. 2011; Mallet and Pelletier 2014).

A utilização desses recursos tecnológicos permite a realização de estudos, como a investigação da composição de comunidades de macrofauna e macroflora bentônica. Dessa forma, um patamar de referência pode ser estabelecido para o monitoramento dessas comunidades permitindo detectar alterações causadas por stress antropogênico e ambiental. Além de auxiliar na criação de modelos para previsões de distribuição de espécies para contribuir na conservação dos ecossistemas recifais (Roelfsema et al. 2013; González-Rivero et al. 2016).

O uso de informações oriundas de dispositivos automatizados apresenta uma série de vantagens (Harvey et al. 2004; González-Rivero et al. 2016), tais como a redução do tempo gasto em saídas de campo, habilidade de amostrar extensas áreas e ambientes profundos, e distúrbio mínimo da fauna (Althaus et al. 2015). No entanto, esses equipamentos não substituem amostragens para coleção de trabalho taxonômico, ou ainda para fins mais detalhados e específicos de diferentes abordagens de pesquisa (e.g. investigação de doenças, ambientes rasos, levantamento de lista de espécies).

Em ambos os casos, necessita-se de uma adequação e padronização de metodologias de coleta para as amostragem entre diferentes pesquisas. E desse modo, possibilitar a calibração entre os resultados para amplificar a potência de cada estudo isoladamente, integrando-se em outros contextos, escalas mais amplas e/ou aumentando sua acurácia. Esse já é um debate histórico revisto por muitos dentro de pesquisas que utilizam o tradicional SCUBA (Brown et al. 2004; Underwood and Chapman 2005; Leujak and Ormond 2007), e mais recentemente vem sendo tratado diante da aplicação em pesquisas que utilizam veículos automatizados para amostragem.

Dentro desse debate, exemplos consistentes metodológicos sobre o modo de operação de ROV's e AUV's são encontrados em trabalhos de mapeamento de comunidades bentônicas em larga escala, por exemplo, em recifes de corais do Caribe, Itália e Austrália (Armstrong et al. 2010; Williams et al. 2012; Cánovas-Molina et al. 2016). Esses modos incluem controle de velocidade e distância do fundo dos veículos, e posição integrada que é fornecido normalmente por equipamentos acústicos integrados ao sistema. Para metodologias de coleta para amostragem, encontram-se trabalhos que utilizam distâncias mínimas a serem amostradas entre locais, intercalação espacial, como também o balanceamento das imagens a serem selecionadas (Williams et al. 2012; Bryson et al. 2013).

Juntamente com a ampliação da capacidade de investigação das comunidades marinhas gerada pelo uso desses dispositivos automatizados, urge um novo desafio de lidar com uma alta quantidade de informação gerada (e.g. banco de horas de imagens) de forma acurada e otimizada. Dessa forma, o uso de dados para estudos de ecologia epibentônica, provindos de imagens de fotos ou vídeos, requer escolhas adequadas de metodologias para analisá-las, sendo interessante levar em conta uma maior padronização das categorias da biota a serem identificadas nas imagens. Isso justifica-se devido ao fato de que os arquivos de imagens e meta-dados associados representam um registro permanente do ambiente em determinado momento e local, e dessa forma podem ser reutilizados e até reanalisados entre diferentes *data sets* para serem direcionados a novas questões de investigações em outras escalas (Althaus et al. 2015).

Dentro dessa perspectiva, já existem algumas propostas de esquemas de identificação e classificação da biota bentônica e do tipo de substrato a partir de imagens subaquáticas (e.g. Madden et al. 2009; Last et al. 2010; Costello et al. 2013). E, ainda mais recentemente, o exemplo do CATAMI (Collaborative and Automated Tools for Analysis of Marine Imagery) que vem tentado consolidar a criação de um vocabulário de identificação para ser adaptado globalmente, através de um esquema que combina um nível de taxonomia mais "grosso" (e.g. gênero) e morfológico com uma classificação hierárquica (Althaus et al. 2015). Essa proposta está totalmente documentada e é mantida através de uma plataforma *online* livre para poder ser aplicada entre diversas coleções de bancos de imagens (CATAMI 2014).

Destaca-se aqui mais uma oportunidade única de análises poderem gerar informações a fim de complementar e otimizar diferentes pesquisas relativas às questões de conservação do ecossistema marinho para o adequado manejo dessas áreas. Como, por exemplo, avaliar os diferentes habitats do fundo oceânico e suas respectivas ameaças (Przeslawski et al. 2011).

Nessa temática, o presente trabalho visou caracterizar e quantificar a estrutura, a prevalência e a abundância dos grupos dominantes da comunidade de macrofauna e macroflora epibentônica entre 10 - 130 metros de profundidade em Vatu-i-Ra no Mar de Coral do Oceano Pacífico nas ilhas Fiji, por meio da utilização de um ROV e da classificação proposta pelo CATAMI.

CONTEXTUALIZAÇÃO DO LOCAL

A República de Fiji é um arquipélago composto por mais de 300 ilhas no sul do Oceano Pacífico - área globalmente considerada com alta diversidade de corais (Hoffmann 2002) - em que seus habitantes tem aprendido a coexistir com o oceano por séculos (Tawake and Hoffmaister 2010). Onde o mar é grande território.

A região de Vatu-i-Ra é situada entre as duas principais ilhas de Fiji – Viti Levu e Vanua Levu (Figura 1) . A região contém uma vasta gama de complexos habitats marinhos, incluindo recifes de barreira, recifes de franja, montes submarinos, manguezais e canais profundos entre recifes (Marnane et al. 2003). A maioria dos seus recifes são envoltos por fortes correntes, as quais trazem grandes quantidades de plâncton oceânico que resulta em ecossistemas recifais altamente produtivos (Marnane et al. 2003). Dessa forma, os recifes de Vatu-i-Ra são tipicamente caracterizados por um crescimento exuberante de corais que aproveitam as águas ricas em nutrientes, contando com uma diversidade de mais de 300 espécies de corais (Jupiter et al. 2012) como as coloridas dendrófitas, gorgônias, e corais azuis (*Heliopora* spp.). Também, é um local onde situam-se populações residentes da tartaruga verde (*Chelonia mydas*) e cabeçuda (*Caretta caretta*); e um dos poucos santuários remanescentes para os globalmente ameaçados peixes-napoleão (*Cheilinus undulates*).

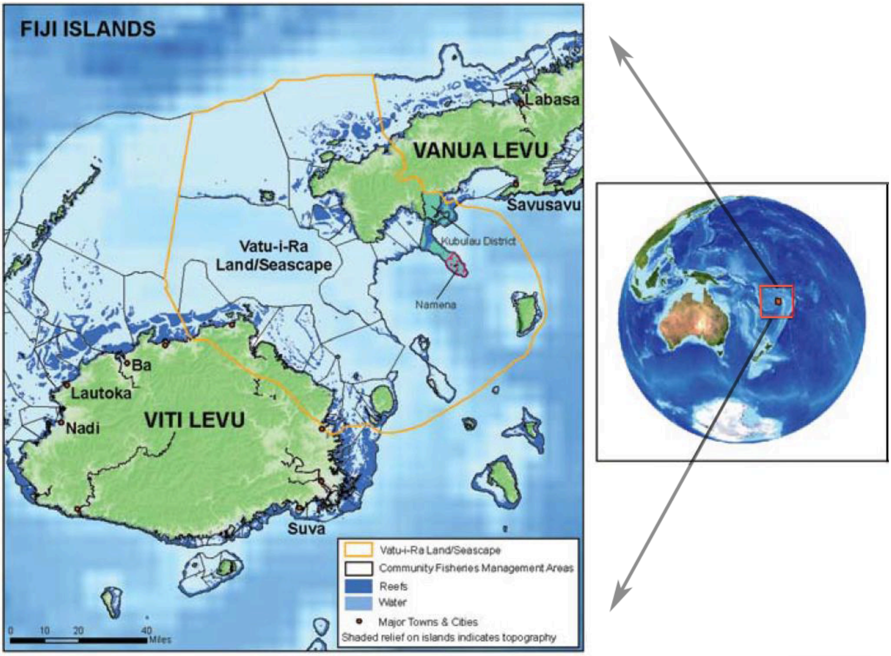

Figure 1. Localização da região de Vatu-i-Ra demarcada pela linha laranja entre as duas principais ilhas de Fiji – Viti Levu e Vanua Levu. As áreas tradicionalmente manejadas *qoliqoli* estão demarcadas pelos polígonos em preto. A direita localização de Fiji no mapa. Fonte: http://fijiseascape.com/wcs/

Dentro dessa forte relação direta dos fijianos com o oceano, principalmente como fonte de subsistência, Fiji conta com o tradicional manejo comunitário das zonas marinhas pelos ilhéus na determinação das áreas denominadas *tabus*. Essas áreas estão localizadas dentro de faixas costeiras que são consideradas propriedades (chamadas *qoliqoli)* de determinadas comunidades para a atividade de pesca, passadas de geração a geração. As áreas *tabus* são uma pequena porção marinha temporária de proteção determinada pelo chefe da comunidade, em que não é permitido nenhum tipo de atividade por cerca de 100 dias (Fiji Locally Managed Marine Areas Network 2011).

Diante da preocupação do atual cenário do aumento das pressões antrópicas, principalmente das atividades de exploração dos recursos naturais das indústrias pesqueiras, mineradoras, e também turísticas nas últimas décadas nos oceanos tropicais do Pacífico (Gillett

2009; Jupiter and Egli 2010), desde o ano 2000 Fiji aderiu à Rede de Áreas Marinhas Protegidas Localmente (*Locally Managed Marine Areas Network* – LMMA) que atualmente incluem o sudeste da Ásia, Melanésia, Micronésia, Polinésia e as Américas. A LMMA Fiji visa constituir a regulamentação de uma rede de áreas marinhas protegidas (MPA's) tanto conectando como integrando as áreas *tabus* dos *qoliqoli,* para deste modo garantir uma maior efetividade de conservação da biodiversidade marinha. Essa regulamentação tem como base princípios de manejo costeiro integrado, que conta com a parceria e participação dos membros das comunidades, líderes tradicionais, equipes de diversas instituições ligadas à conservação (WCS[1], IUCN[2], Coral Reef Aliance, etc.), pesquisadores e universidades parceiras, donos de empresas, e, por fim, gestores que são eleitos entre eles próprios (Fiji Locally Managed Marine Areas Network 2011).

A abordagem do manejo e proteção local tradicional inclui em sua maior parte áreas costeiras, não incluindo as áreas oceânicas. Dessa forma, as áreas marinhas oceânicas de Fiji encontram-se em grande parte vulneráveis. Além de estarem sendo reportados como alvo de atividade de pesca ilegal, encontram-se desregulamentadas frente à atividades industriais provindas principalmente de fora do país (Marnane et al. 2003), como por exemplo dragagem para mineração e a pesca industrial.

Dentro desse contexto, as áreas oceânicas de Vatu-i-Ra do Mar de Coral – local de estudo do presente trabalho – necessitam ser protegidas para a manutenção dos processos ecológicos. Vatu-i-Ra, além da relevância ecológica de seu biodiversos ecossistema recifal, é uma região de alta importância para a subsistência da população tradicional.

Desde o ano de 2005, a Wildelife Conservation Society (WCS) tem se dedicado ao auxílio para a implementação de MPA's em áreas oceânicas, e, a partir de 2010, lançou a campanha nacional de proteção de toda a região de Vatu-i-Ra. Foi dentro dessa campanha, que tive a oportunidade de vivenciar durante o estágio de um período de dois meses um pouco do trabalho de subsídios e desenvolvimento de MPA's em áreas oceânicas na escala de Vatu-i-Ra, como suporte para gestão pesqueira e conservação da biodiversidade. E, mais especificamente, participei da investigação das comunidades epibentônicas de quatro locais dentro de Vatu-i-Ra, que foram explorados pela primeira vez na

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[1] Wild Life Conservation Society

[2] União Internacional para a Conservação da Natureza

expedição da WCS, em parceria com Waitt Institute durante o período de 19-23 de setembro de 2013.

Dessa forma, o intuito do presente trabalho de conclusão de curso, além de desenvolver minhas capacidades como futura bióloga, é de ser também uma devolutiva científica de todo incentivo financeiro concedido pela bolsa que obtive, o qual retrata parte das atividades que desenvolvi como intercambista.

O estudo apresentado a seguir encontra-se em capítulo único em língua inglesa formatado de acordo com as normas da revista Coral Reefs.

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ARTIGO

Using robots to unveil the mysteries of deep reefs in Fiji: from 10 to 130 meters

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Using robots to unveil the mysteries of deep reefs in Fiji: from 10 to 130 meters

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Abstract

Depth is a well established surrogate of benthic species distribution in marine ecosystems. However, most studies focused on reefs shallower than 30 meters, therefore we know little about community structure across depth gradient from shallow to mesophotic reefs. Here we used remotely operate vehicle and species distribution models to assess the effect of depth on the epibenthic community composition from 10 to 130 meters depth, in coral reefs of Vatu-i-Ra seascape, Fiji. Depth was significantly related to the presence and abundance of three out of four epibenthic groups. Stony coral abundance decreased with depth, while octocorals and macroalgae increased with depth up to 40 – 50 m and then decreased with depth. Other invertebrates, such as sponges and ascidians, were relatively abundant (>30%) across all depths, as well the taxa algae. This study demonstrates how imagery from remotely operated vehicles can be used to characterize the benthic community composition across a broad depth gradient and advances our knowledge of the function of mesophotic coral reefs. It is one in a handful of studies that describes the entire epibenthic community composition beyond 30 meters depth.

Key words: Depth, coral, octocoral, surrogate, mesophotic coral communities, sponges, ascidians, Fiji, Coral Sea.

Introduction

Coral reefs are the most biodiverse marine ecosystem in the world, and they are economically important by providing ecological services, such as tourism, shoreline protection, fisheries, aesthetic and cultural values (Bellwood et al. 2004; Hoegh-Guldberg, et al. 2007). Yet coral reefs are highly threatened, suffering continuous deterioration caused mainly by anthropogenic activities at both global and local scales, such as the overfishing, pollution, ocean acidification, global warming, algal blooms, disease prevalence, and invasive species (Hughes et al. 2003; Mumby and Steneck 2008). Clearly, an improved understanding of the structure and dynamics of coral reef systems is urgently needed to aid conservation efforts in maintaining and enhancing the diversity and function of the reefs.

Depth is widely accepted as a surrogate of the distribution of epibenthic communities, where most species have predictable and restricted depth ranges (Gray 2001; McArthur et al. 2010). It is not surprising that depth is one of the most useful surrogates of marine ecosystem classification, as well as substrate type, and sea floor geomorphology (Howell 2010). However, the vast majority of studies conducted on coral reefs have focused on reef habitats above 30 meters depth, a limit usually imposed by the depth limit of traditional SCUBA. This represents a critical gap in the knowledge of coral reefs (Pyle 2000; Lesser et al. 2009; Bridge et al. 2011).

Recent technological advances, such as the optical imagery of autonomous underwater vehicles and remotely operated vehicles (ROV), enable new observations and thus new fields of research including investigation on deeper reefs. These images can address specific biodiversity-related topics dealing with habitat mapping and epibenthic cover across multiple spatial scales through an integrative approach that considers geomorphological, ecological and even biophysical data (Althaus et al. 2015; González-Rivero et al. 2016). For example they can provide taxa zonation at multiple scales, testing effects of marine protect zones, and interaction of other biotic and abiotic factors. Research studies that characterize marine communities from shallow to mesophotic reefs can explain and identify factors that influence the distribution patterns of coral reef communities, thus improving reef management (Post et al. 2006; Bridge et al. 2011). Different scheme proposals to characterize the communities exist. They go from local and species level perspective to a broader global standardization scheme that is based on an ecosystem function approach through the use of a hierarchical morphogroup classification (e.g. Madden et al. 2009; Last et al. 2010; Althaus et al. 2015).

These novel imagery technologies for identify benthic habitats have been increasingly used around the globe, for example monitoring programs of Australia, Alaska, Britain, New Zealand, and Asia (Diaz et al. 2004; Bridge et al. 2011; Mallet and Pelletier 2014). As technologies became available for investigating epibenthic communities, they present a unique opportunity to explore unknown depths and cover larger geographical areas and consequently, monitoring baselines can be established (Mumby et al. 2004). In turn, these types of studies can facilitate powerful species distribution models and predictions to improve conservation of coral reefs and associated ictiofauna (Roelfsema et al. 2013).

This study uses imagery obtained using a ROV to characterize the epibenthic community composition of Fijian coral reefs across a depth gradient spanning 10 – 130 meters. A morphological hierarchical scheme (CATAMI 2014) was used to classify the biota and substrate type to the highest taxonomic resolution possible. Species distribution models were used to investigate quantitatively the influence of depth on epibenthic community composition. We predicted that taxa that depend on light, such as corals and algae, would decrease with depth, and that as space became available from lower competition, the abundance of other taxa would increase with depth.

Methods

Study area/ Physical environment

Fiji main islands - Vanua Levu and Viti Levu - have a moderate, tropical climate with a distinct wet season, generally recognized as the cyclone season, between November and April. Fiji experiences about 10 to 15 cyclones per decade, two to four of which cause severe damage including extensive wind damage, flooding, storm surges and occasional landslides (Jenkins 2004). Rainfall is highly variable, even in the wet season, and is predominantly influenced by the prevailing southeast trade winds and local topography. Annual rainfall averages 1.78 to 3.18 cm, with weak seasonality. Temperatures range from 19.8 C^o to 30.6 C^o (Fiji Meteorological Office). The average yearly temperature is about 25 $C^{o.}$

The Vatu-i-Ra Seascape is located at the center of the two main islands. It covers over 20,000 km^2 of relatively intact reefs, seagrass meadows, mangroves, rivers, and forest, and it is considered one of Fiji's last great wild places. It is an adjacent area of the third longest barrier reef system in the world and one of the 35 priority conservation areas identified. Characterized by the diversity of reefs, seamounts and deep channels with strong currents that nourish a magnificent diversity of more than 300 species of corals. The most important current is "Bligh Waters", a fast flowing current which runs from east to west separating Vanua Levu and Viti Levu within Vatu-i-Ra passage (Drew and Barber 2012).

Study Design / Data collection

The sites were surveyed during spring of 2013 to avoid potential confounding seasonal effects. Four randomly spaced sites were selected: Vatu-i-Cake site 1 on September 22st (178’31.2954”E, 17’20.76306”S); Vatu-i-Cake site 2 on September 23st (178’49.1557”E, 17’24.82905”); Namena on September 24st (179’04.598”E, 17’07.734”S); and E6 on September 26st (178’35.565’’E, 17’19.660’’S) - Figure 1. Vatu-i-Cake site 1 and 2, and Namena are located at the barrier reefs. They are adjacent to deep water (>500 m) system off the outer reef edge. While, E6 is seamount rising of up to 1000m.

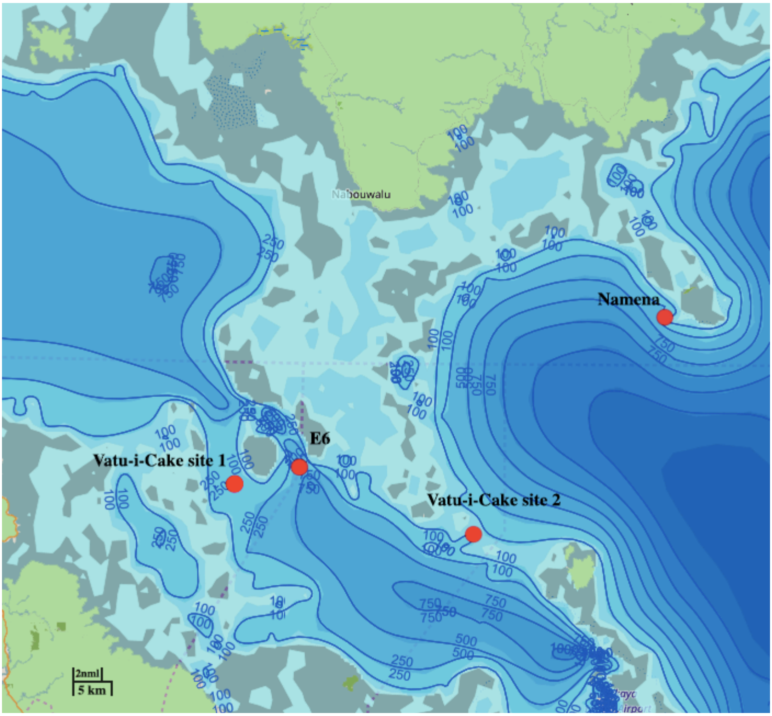

Figure 1. Location of ROV deployments at E6 seamount and on the reef walls of Namena and Vatu-i-Cake barrier reefs in Vatu-i-Ra seascape, Fiji islands. Location on the world of Fiji at top right.

These assemblages were surveyed using the "Waitt Saab Seaeye Falcon" ROV dep1oyments, which navigated at ~2 m above the seafloor recording continuously throughout each deployment with a high-definition video camera. The Waitt ROV uses an integrated navigation system consisting of an Imagenex 881A Sonarand Tracklink navigation system. ROV position data (including latitude, longitude and time/date) were logged every 2-5 seconds during each deployment, and later exported as 'dat' files to Excel.

The ROV was deployed along 10 meter interval horizontal contours to 70 meters and thereafter 15 meter interval contours until 130 meters – resulting in 11 depth profiles surveyed at each location.

The ROV deployments were two hours in duration. The entire video files were analyzed by one trained observer (CA), and frame grabs of the video files were taken every minute along 10 minute periods per depth per site (see supplementary material, Appendix S1). The sample units were 10 images / per depth, resulting in 440 images analyzed (110 images per site) for the study area. The video camera used to capture the images used here has an approximate field of view of 42×34 degrees for the images. At a typical altitude of 2 m, this corresponds to an image approximately 1.5 m by 1.2 m, with an area of approximately 1.8 m^2. The non-flat nature of the sea floor, and camera geometry, mean that these measurements should not be considered precise. The altitude of each image is provided in the data set, so some spatial scaling can be made. The 440 images analyzed refer to approximately 720 m^2 (110 images per site = 198m^2).

Data processing

All 440 images were analyzed by overlaying 25 random points (see discussion of marine science literature using up to 50 points per image can be found in Bewley et al 2015) using Coral Point Count with Excel extensions (Kohler and Gill 2006). The epibenthic community composition was categorized based on a simplified scheme of The Collaborative and Automated Tools for Analysis of Marine Imagery (CATAMI) Version 1.2 classification (Althaus et al. 2013) used to identify organisms to a morpho-family level (Table 1), with the exception of other invertebrates group. The CATAMI classification uses a hierarchical approach (*e.g.* biota: cnidarians: Black & Octocorals: fan (2D)), which allows testing for effects at different levels of the taxonomical hierarchy. Both coarse and fine taxonomic categories were used in this study (Table 1). For other invertebrates category was not used a morpho-family level approach (see supplementary material, Appendix S2).

Table 1. Dominant sessile epibenthic categories were based on the simplified version of CATAMI classification to a morpho-family level. While other morphs were present in the study area, the taxa presented in this table were the most abundant in this study.

Taxonomic category: coarse	Taxonomic sub-category: fine
Stony Corals	Acropora; non- Acropora (NA), NA:Encrusting; NA:branching; NA: massive; NA:Solitary
Black & Octocorals	Encrusting; branching; massive; whip
Macroalgae	Erect; turf; crustose; articulated calcareous
Other Invertebrates	Sponges/ascidians; crinoids
Unknown	Encrusting; massive; branching

The substrate type was classified by the physical appearance of the seabed described according to the appearance based on the hierarchical scheme of CATAMI Version 1.2, which has two major subdivisions: (1) unconsolidated and (2) consolidated. Within the major divisions there are six classifications of substrate type in total – (1) Consolidate: Cobbles; (2)Consolidated: Rock; (3)Consolidated: Boulders; (4)Unconsolidated; (5)Unconsolidated: Pebble/gravel; and (6)Unconsolidated: Sand-mud (Althaus et al. 2013). Relative abundance was quantified as the percent cover of each epibenthic category and sub-category (Table 1). Mean values were calculated at each depth (10-130m) for both coarse and fine taxonomic groups. Coarse categories were plotted for each depth separately, and pooled across sites to visualize the epibenthic composition across the surveyed depth range. Fines sub-categories were plotted for each coarse category (with exception of other invertebrates) separately for each depth to examine the distribution of sub-categories across the surveyed depth zonation.

Data Analyses

Multivariate Analyses

We used permutational multivariate analysis of variance (PERMANOVA) with PRIMER 6 PERMANOVA+ (PRIMER-E 2007) to investigate the relationship between epibenthic community abundance - for both coarse and fine groups - and three types of explanatory variables: depth (continuous), site (random), and substrate type (categorical). Data were square-root transformed and Bray-Curtis dissimilarity matrices were constructed for all models. Models were reduced following the parsimony principle via backwards elimination. Final multivariate plots were made using Excel. Principal Component Analysis – PCA- (Kelechi 2012) was used with PRIMER 6 PERMANOVA+ (PRIMER-E 2007) to examine the dimensional occupancy of the sample units according to abundance of coarse groups along the investigated depths.

Univariate Analyses

Generalized hierarchical models were used to further investigate the effect of depth on the coarse epibenthic groups: stony corals, black & octocorals, macroalgae, and other invertebrates. This analysis determined the relationship between the abundance within each group and the two types of explanatory variables: depth (10 - 130 m), and substrate type (six variables). We used linear, generalized mixed effects (GLMM) and zero-inflated two part models (e.g. ZINB glmer) in R packages *nlme* (Pinheiro et al. 2013), *lme4* (Bates et al. 2013) and *mass* (Venables and Ripley 2013). Site was tested as random effect and if not significant ($p>0.05$) was removed from the models (Zuur et al. 2009). The explanatory variables were tested for collinearity (Spearman collinearity test), and only uncorrelated ($p < 0.7$) variables were included in the same model (Sleeman et al. 2005; Leathwick et al. 2006). The choice of model was informed by the need to account for (i) random effects of site, (ii) potential zero inflated and/or (iii) over-dispersed abundance data. Models were reduced following the parsimony principle and tested using *Chi-square* test on likelihood ratios and Aikaike Information Criterion (AIC) to determine the best model. Assumptions of heterogeneity, normality (if applicable) and linearity were checked using residual plots in all final models. The model selected for stony corals was a zero-inflated negative binominal mixed-effect model; for black & octocorals was a zero-inflated binominal mixed-effect model; for macroalgae was a linear poisson mixed-effect model; and for other invertebrates was a generalized linear poisson mixed-effect model with the interaction between the different types of substrate.

Results

Overall, the mean values of the coarse categories show a high abundance (>40%) of macroalgae across all depths (10-130m) in all sites, followed by other invertebrates abundance (>30%). Stony corals exhibit a negative trend related to depth increase, which is opposite to the trend observed for the bare substrate (Fig. 2).

Stony corals abundance decreased until 40 m depth, followed by a percent cover of less than 5% between 40 and 70 m depth, and less than 1% cover below 70 m depth. Black & octocorals abundance increased from 10 to 40 m, and it decreased bellow 40 m. It maximum abundance occurred at 60 m. And this group was still recorded at 130 m. Macroalgae abundance was high and increased from 10 to 50 m, with a significant drop and subsequently unclear trend bellow 50 m. The abundance of other invertebrates, composed manly by sponges and ascidians, increased with depth until 85 m, and thereafter presented an unclear pattern, but was still abundant (>30%) on deeper reefs. Lastly, the amount of bare substrate increased with depth, with two major drops in biota abundance at 60 and 85 m.

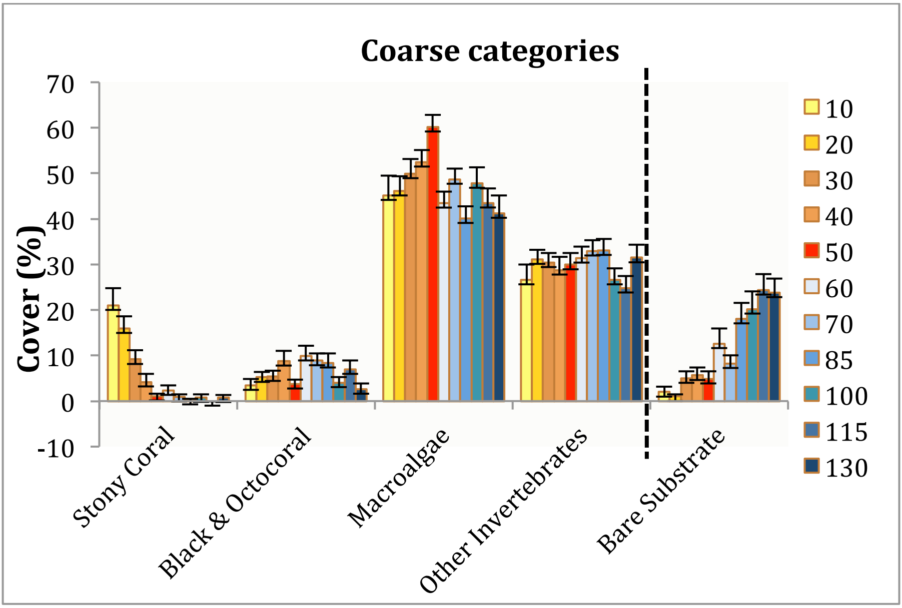

Figure 2. Mean epibenthic percent cover by coarse groups across depth zonation (10-130m) of the four sites pooled in Vatu-i-Ra seascape, Fiji islands. Error bars denote standard error.

Major differences within the two nearest sites (Vatu-i-Cake site 1 and Vatu-i-Cake site 2) were detected regarding the stony corals abundance at shallow reefs. Where site 1 shows 50% to 15% percentage cover, while site 2 shows less than 10% cover abundance (Figure 3). The trend of macroalgae abundance is also opposite within these sites. The site 1 shows an increase trend related to depth, while site 2 presented a decreased trend (Figure 3). Bare substrate shows increasing trend across depth range with exception of E6 site, which shows no bare substrate (Figure 3).

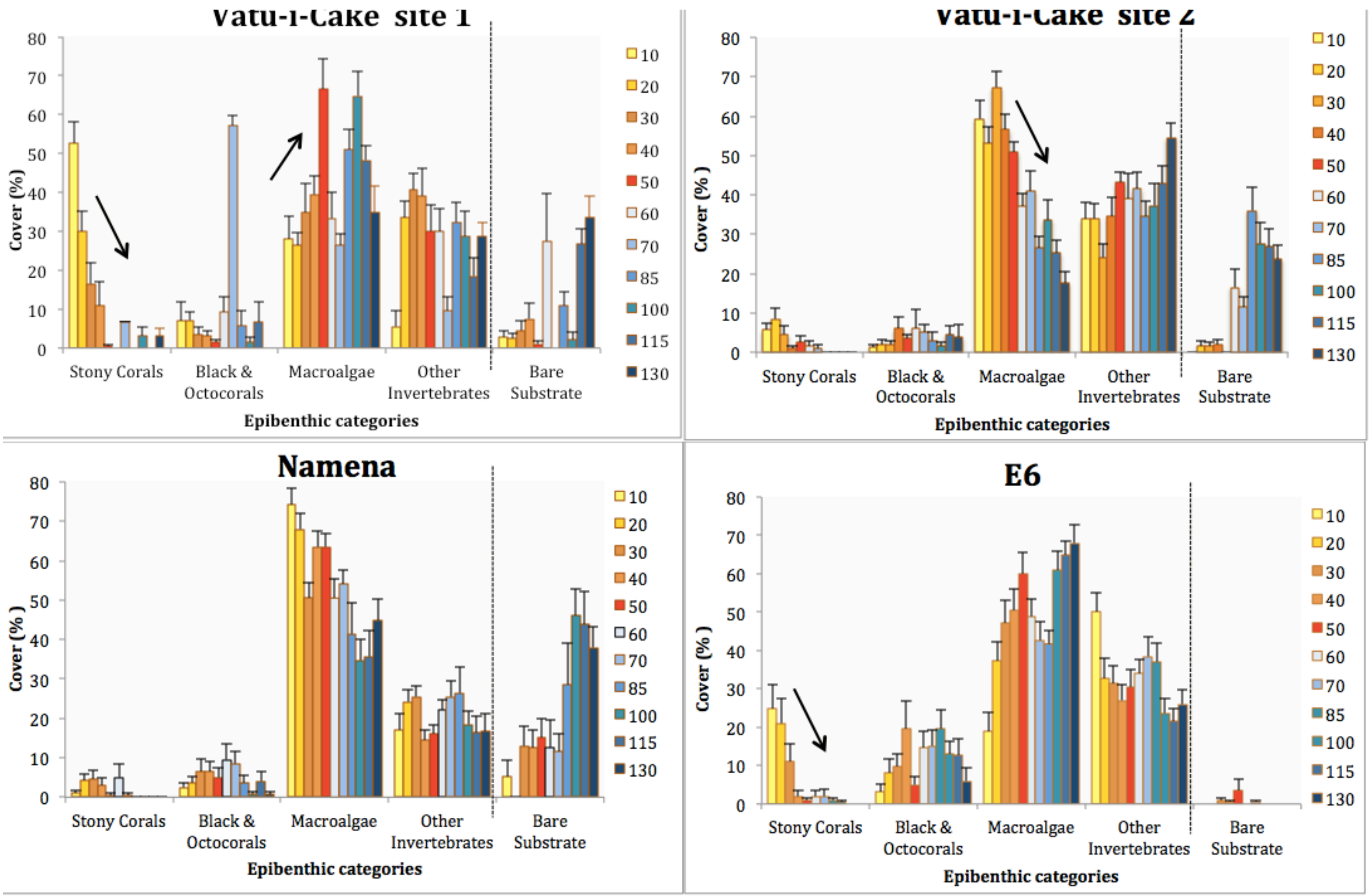

Figure 3. Mean epibenthic percent cover by coarse groups across depth zonation (10-130m) of Vatu-i-Cake site 1, Vatu-i-Cake site 2, Namena and E6 in Vatu-i-Ra seascape, Fiji islands. Error bars denote standard error. Arrows indicate trend patterns.

Within stony corals taxa at shallow reefs the dominant sub-category was "encrusting non-*Acropora*" ranging from 3% to 7,5% abundance (Figure 4). "*Acropora* tabulate" and "encrusting non-*Acropora"* presented more than 1% cover abundance at 40 m depth (Figure 4). Below 40 m depth "*Acropora"* were no detected animore, except the "tabulate" at 130m (Figure 4). Within 50-60 m depth the "foliose" and the "solitary/mushroom" were the prevalent and the most abundant (>1%). Below 60m depths the "solitary/mushroom" was detect across all depth ranges (Figure 4).

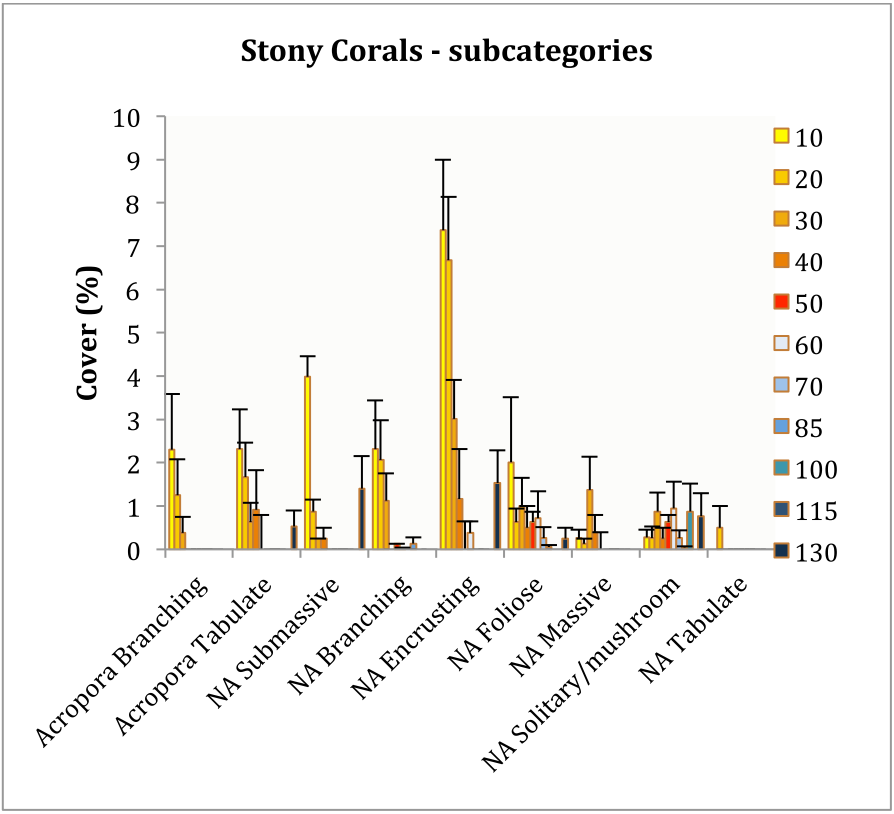

Figure 4. Mean epibenthic percent cover by fine sub-categories of stony corals across depth zonation (10-130m) of the four sites pooled in Vatu-i-Ra seascape, Fiji islands. Error bars denote standard error. NA: Non-*Acropora*.

Within black & octocorals taxa the "branching" type was the most prevalent and abundant along all depth zonation, with a major peak (>5%) within 50-60 m depth (Figure 5). The "fan" types were the next more prevalent and abundant (<4%) across all depth range. "Encrusting" was not detected bellow 30 m depth (Figure 5). "Whip" showed a slightly positive trend until 70m depth, and after a more constant pattern to 115 m with a drop at 130 m depth (Figure 5).

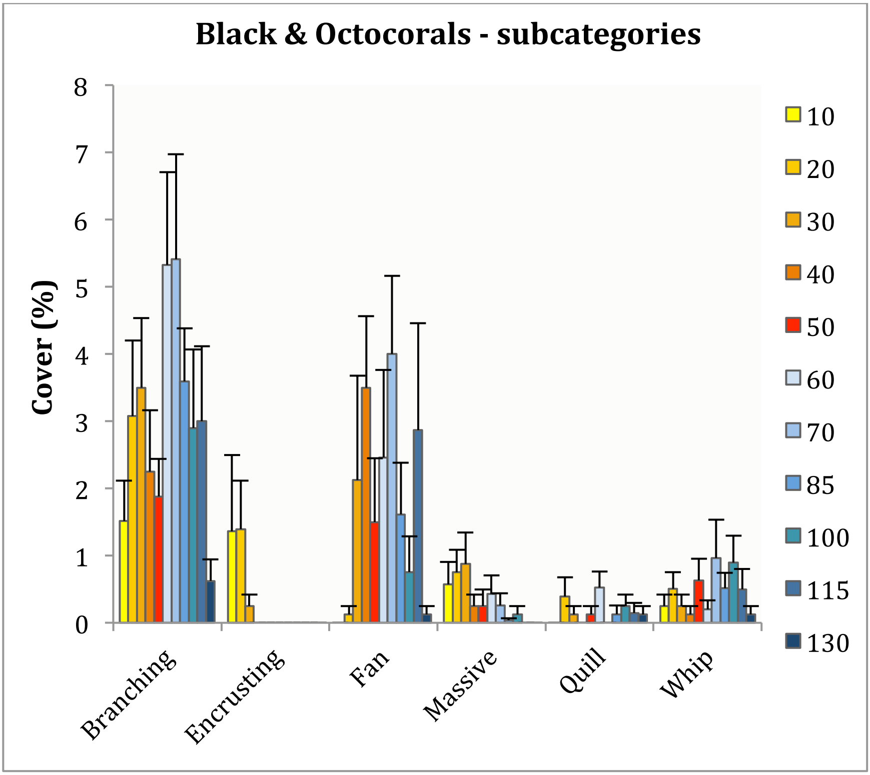

Figure 5. Mean epibenthic percent cover by fine sub-categories of black & octocorals across depth zonation (10-130m) of the four sites pooled in Vatu-i-Ra seascape, Fiji islands. Error bars denote standard error.

"Turf" algae was prevalent and highly abundant (>20% to <40%) along all depth range (Figure 5). The next most prevalent and abundant (< 20%) was "crustose coralline" macroalgae that showed a increasing trend to 50 m depth with a drop at 60 m depth followed by negative trend (Figure 6). “Erect” macroalgae was abundant (5%) at 10 m depth and it presented a clearly decreasing trend across depth range (Figure 6). “Articulated calcareous” also presented a decreasing trend along depth zonation and it was not more detect bellow 60 m depth (Figure 6).

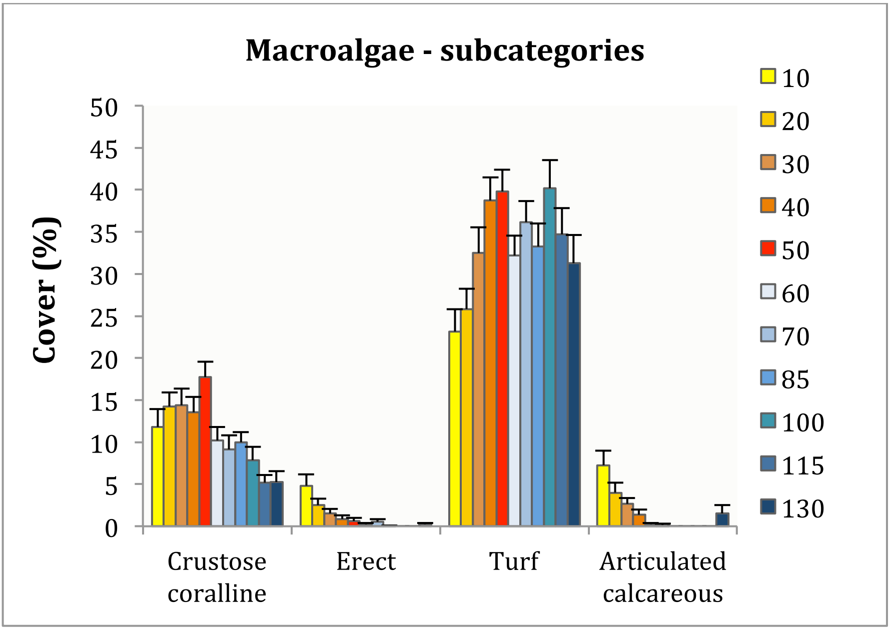

Figure 6. Mean epibenthic percent cover by fine sub-categories of macroalgae across depth zonation (10-130m) of the four sites pooled in Vatu-i-Ra seascape, Fiji islands. Error bars denote standard error.

All taxa that were identified at genera level were arranged in a table along all depths for further investigations (see supplementary material, Appendix S3).

PERMANOVA Multivariate analyses indicated that both coarse and fine sessile epibenthic categories varied significantly with the interaction of depth and site, suggesting that the influence of depth on epibenthic abundance varies with site (Table 2). The interaction of depth and substrate was also significant for coarse group, but not for the fine group; while the interaction of site and substrate was significant for both the fine and the coarse groups (Table 2). Both models had a high adjusted R-squared (Table 2) and were identified as suitable grouping to investigate the relationship between depth and sessile epibenthic abundance.

Table 2 PERMANOVA results for the coarse and fine group models of sessile epibenthic categories at four sites in Vatu-I-Ra seascape, Fiji Islands. Adjusted R-square was calculated through the equation R^2_{adj}= 1- ResidualMS/TotalMS. Non-significant variables are greyed out. df: degrees of freedom.

Coarse group		**Adjusted R-squared:**	**0.9477**
	df	Pseudo-F	*p*
Depth	10	2.9649	0.002
Site	3	11.759	0.002
Substrate	5	0.7207	0.641
Depth x Site	20	4.7581	0.001
Depth x Substrate	27	1.4335	0.023
Site x Substrate	8	1.8326	0.047
Fine Group		**Adjusted R-squared:**	**0.9478**
	df	Pseudo-F	*p*
Depth	10	2.1063	0.001
Site	3	3.1294	0.007
Substrate	5	0.7767	0.663
Depth x Site	20	3.9835	0.001
Site x Substrate	8	1.6025	0.029

The PCA was used to spatially visualize the community composition within the study area by plotting the abundances for the coarse group categories. After logarithmic transformation of the variables, the PCA first and second axis accounted for 39.6 and 21.7% of the total variance respectively (Figure 7). General trends were ecologically relevant, the spatial occupancy showed that deeper reefs were dominated by bare substrate. Macroalgae dominated intermediate depth reefs. Black and octocorals as well, as other invertebrates were dominant in shallower mesophotic reefs. And stony corals dominated shallow reefs.

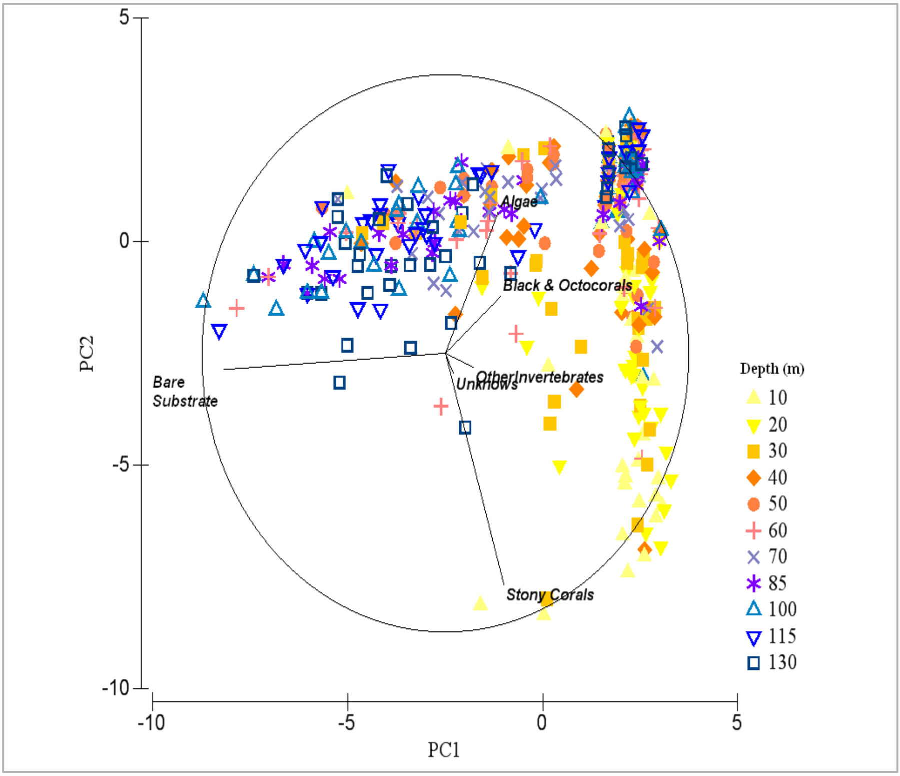

Figure 7. Results of the normalised principal component analyses (PCA) for the sample units. Hot colors represent shallow reefs and cool colors correspond to deeper reefs. Axis PC1 represents eigenvalue of major data variance (39.6% Variation) and axis PC2 represents the next eigenvalue of major data variance (21.7% Variation).

For the univariate analysis the type of substrate was tested as a potential explanatory variable, but was only significant in the abundance of other invertebrates, thus it was removed from all other final models. Stony coral occurrence and abundance significantly decreased with depth. Interestingly, despite the trend observed in Figure 2, depth had no significant influence on either occurrence or abundance of black & octocorals. Similar to stony corals, macroalgae abundance was also negatively and significantly influenced by depth. The abundance of other invertebrates decreased significantly with depth, but this influence changed according to the interaction of substrate type (Table 3).

Table 3. Summary of final models for each coarse sessile epibenthic category at four sites in Vatu-I-Ra seascape, Fiji Islands. Non-significant covariates that were kept in the final model are grayed out. Zero inflated two-part model (Presence/absence and Abundance data) was selected for stony corals and black & octocorals groups, while the models for macroalgae and other invertebrates groups estimated only abundance data. SD: standard deviation.

Model Type: ZINB glmer			
Stony Corals		Presence/Absence	
	Coefficient	Estimate	Pr(>|z|)
	Intercept	1.348	<0.001
	Depth	-0.047	<0.001
		Abundance	
	Coefficient	Estimate	Pr(>|z|)
	Intercept	3.129	<0.001
	Depth	-0.012	<0.001
Random effects		SD	
Site		0.446	
Model Type: ZINB glmer			
Black & Octocorals		Presence/Absence	
	Coefficient	Estimate	Pr(>|z|)
	Intercept	0.035	0.92
	Depth	-0.004	0.12
		Abundance	
	Coefficient	Estimate	Pr(>|z|)
	Intercept	2.439	<0.001
	Depth	-0.012	0.24
Random effects		SD	
Site		0.189	
Model Type: lme			
Algae	Coefficient	Estimate	Pr(>|z|)
	Intercept	51.038	0
	Depth	-0.058	0.024

	Model Type: glmer poisson		
	Coefficient	Estimate	Pr(>|z|)
Other Invertebrates	Intercept	2.284	<0.001
	(Boulders)	0.011	<0.001
	Depth	1.169	<0.001
	Cobbles	1.063	<0.001
	Rock	1.568	<0.001
	Unconsolidated	1.902	<0.001
	Pebble/gravel	0.935	<0.001
	Sand-mud		
	Depth x Cobbles	-0.012	<0.001
	Depth x Rock	-0.01	<0.001
	Depth xUnconsolidated	-0.014	<0.001
	Depth x Pebble/gravel	-0.021	<0.001
	Depth x Sand-mud	-0.01	<0.001
Random effects		SD	
Site		0.225	

Discussion

Community Composition

ROV surveys across a depth zonation of 10 – 130 m within Vatu-I-Ra Seascape region revealed high (>40%) epibenthic cover on the entire reef community. Despite some differences across sites, the overall patterns observed for the coarse groups (stony corals, black and octocorals, macroalgae and other invertebrates) were consistent across sites, as well for the fine sub-categories.

Stony corals decreased with depth. Since the majority of corals identified in this study host zooxanthellate, they appear to be directly related to depth, but still occur in the middle to lower photic zone as defined by mesophotic coral ecosystem – MCE – from 30-130 m (Kahng et al. 2010; Bridge et al. 2012). These findings contribute to a growing body of knowledge of coral communities in mesophotic reefs, for example in the Coral Sea east of the Great Barrier Reef – GBR- (Australia) a diverse community of hard corals were recorded as deep as 102 m depth, but not recorded below 150 m (Bongaerts et al. 2011).

Other surveys confirm that although zooxanthellate scleractinian corals were often scarce below ~80 m depth, stony corals have been found extending to depths similar to the ones surveyed in this study. For example, Bare et al. (2010) and Bridge et al. (2012) reported coral communities composed mainly by plate-like *Pachyseri*s, *Leptoseris* and *Montipora,* at depths of 125 m on the GBR, American Samoa (>7.7% abundance) and the Coral Sea. The plate-like morphology of zooxanthellate corals are frequently recorded on low light environments such as caves and overhangs , because their morphology amplifies light interception per unit mass (Anthony and Hoegh□Guldberg 2003; Roth 2014). In this study, we found that the prevalent types at mesophotic zones were foliose and solitary/mushrooms (~1% abundance) - Figure 4. However, accumulating evidence suggests that mesophotic corals do not conform to a uniform metabolic strategy at depth as different species exhibit distinct and sometimes opposing photo-physiological adaptations to low light. Recent studies ensure that zooxanthellate corals exhibit a variety of strategies for growing in deep water where the available light to drive photosynthesis becomes scarce (Kahng and Wagner 2014).

Black and octocorals were not significantly related to depth. This is interesting especially because of the intermediate depth (peak at 60m) pattern (Figure 2). Could it be that the relationship is not evidenced because they first increase and then they decrease? MCE investigations in American Samoa showed similarly patterns, with an peak in abundance of soft corals around 60 m followed by a decline below 100 m, and presence of this group at deeper depths (Bare et al. 2010). In the Mediterranean Sea, dense populations of the gold coral *Savalia savaglia* were documented at 67 m surrounded by sea-fans forests (Cerrano et al. 2010). In GBR, diverse communities of azooxanthellate octocorals were observed up to 150 m (Bongaerts et al. 2011). Likewise, at Marshall islands azooxanthellate gorgonians and nephtheids dominated the coral community below 100 m, and in the Red Sea azooxanthellate corals - particularly *Dendrophyllia horsti* and *Javania insignis* - are dominant from 130 to 170 m (Kahng et al. 2010). Here, we detect that the most prevalent type were the branching ones, followed by the fan types (Figure 5).

Despite the fact that macroalgae abundance decreased with depth, it was still high on the deeper reefs (>40%). Undeniably it is the dominant benthic group across all depth zones. Liddell et al. (1997) and Aponte and Ballantine (2001) reported that benthic algae also dominated reef communities in Bahamas up to 100 m depth and exhibited vertical zonation by taxa. They also found a depth partition on algal taxa. Macroalgae (*Halimeda spp. and Lobophora spp.)* dominated the reef to 60 m, while filamentous/turf algae remained abundant to 75 m and calcifying algae increased with depth and co-dominated at 75–100 m with endolithic green algae. Below 100 m, calcifying algae declined in abundance and endolithic algae dominated hard substrata to at least 200 m. In this study, we found that turf dominated all depth ranges (10-130m) with more than 30% cover abundance (Figure 6). Also, we found that crustose coraline were present across all depth zonations, with a major drop bellow 60 m depth (Figure 6). Similarly, Hawaiian reefs exhibit higher abundance on macroalgae taxa with zones on 90 – 200 m that contained crustose coralline algae covering 40 - 60% of the substratum (Agegian and Abbott 1985). On the other hand, on American Samoa magroalgae taxa is less abundant, showing an abundance peak (>20%) at 50 m, but declining sharply with increasing depth until 100 m, with < 3% cover (Bare et al. 2010).

Other invertebrates, composed mainly by sponges and ascidians, were also abundant on deeper reefs. The majority of this animals are heterotrophic, thereby they do not exhibit a strong relation with depth luminosity zonation because they are suspension feeders (Ribes et al. 2005) that rely on dissolved organic matter assimilation to fulfill an important part of their energetic needs (de Goeij et al. 2008; Polónia et al. 2015). Also, recent investigations on these groups suggest that microbial symbionts play important roles at mesophotic depths (Olson et al. 2013). As on tropical reefs, 30–50% of sponges are cyanosponges, and cyanobacterial symbionts can provide >50% of their energetic requirements (Webster and Taylor 2012). Indeed, distribution of cyanosponges exceeds both the latitudinal and depth distributions of zooxanthellate corals (Kahng and Wagner 2014).

Depth zonation is one of the major features of coral reefs. Shallow to deeper reefs exhibit a succession of distinct zones, each dominated by different species or groups (Harrison and Booth 2007). However, there are other possible key determinants that should be investigate in more detail to fully support a proper marine spatial planning. As examples of these factors are geomorphological features, temperature, currents, and anthropogenic impacts.

Management and conservation implication

Given the reported and forecasted degradation of reef habitats (Mumby and Steneck 2008; Hughes et al. 2003) the depth range and connectivity of species between shallow and mesophotic reefs have important conservation implications (Slattery et al. 2011; Sinniger et al. 2013). Thus, understanding the composition of its community, the population structure of the main benthic organisms or their health status is crucial towards improving ocean management (Sardà et al. 2005).

Coral reef policies, governance structures and management generally only consider reef habitat shallower than 20–30 m, and often ignore the potential role that mesophotic reefs could play in conservation planning and resource management of the broader seascape. For instance, ecological data used to inform the design of Marine Protected Areas (MPA's) often under-represents mesophotic reefs (Bridge et al. 2013). Effective conservation planning relies on achieving a representative suite of habitat types, where species, ecological processes and ecosystems are protected from threats such as overfishing, pollution (Hughes et al. 2003) and mining (extraction of fossil fuels or metals). These threats are also considered a major perturbation for reef systems, including deep reefs (Clark et al. 2010). Here, we generate baseline data that can contribute to support marine zoning planning and others management actions to protect the remaining marine resources that support people's livelihoods, as well as the astounding biodiversity of coral reef systems.

Threats to coral reefs are ever increasing and typically concentrated on the shallower areas where fishing pressure is most focused and where disturbances such as coral bleaching, storm and other anthropogenic activities are most influential (Bongaerts et al. 2011*;* Bridge et al. 2013*)*. Despite the few studies conducted in MCE's, recent investigations have revealed that these reefs may provide critical refuge habitats (Bare et al. 2010; Kahng et al. 2010; Bridge et al. 2012). Lindfield et al. (2016) suggest that MCE's can provide refuge from shallow-water fishing methods and could be the last stand for threatened coral reef fish, consequently representing key areas for research and management. For instance, in the Red Sea, turnover in fish community composition at mesophotic depths appears highly correlated with a reduction of branching coral abundance (Brokovich et al. 2008). Likewise, in Puerto Rico, high grouper abundance has been observed to peak at 25 m depth, but only in association with *Orbicella* spp., the dominant scleractinian coral at those depths. Also, grouper are associated with high structural complexity reefs at 70 – 100 m depth (Gilmore and Jones 1992; Garcia-Sais 2010). Hence, describing and quantifying patterns of macrobenthic community composition across a wide depth gradient might also serve as a potential surrogate for fish distribution models.

This was a pilot study, while there are not many studies around the world looking at epibenthic community composition across this depth range (10-130 m), they commonly agree on the services provided by MCE's for a healthy function of all coral reef systems. Moreover, hard corals decrease with depth, although they are still present in the lowest photic zone; and macroalgae can be abundant across all depth ranges. Regarding the composition distribution of black and octocorals there are evidences that they are relative abundant at intermediate depths. Also, there are basically no investigations of sponges and ascidians distribution of deeper reef communities. All this information must be taken into account for the regulation of activities that change water turbidity and as a consequence the photic zone for example. More information is needed. Likewise, a compilation of existing data would be very useful to support building powerful predictive models of marine benthic cover, and thus inform spatial conservation management.

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Appendix S1: Experimental design of ROV deployments at the four sites of Vatu-i-Ra Seascape

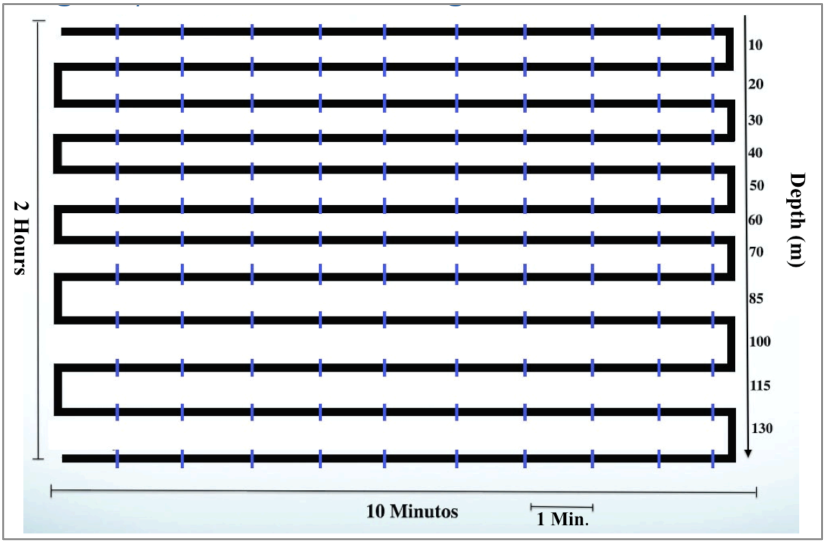

Figure 1. Experimental design of ROV deployments at the four sites of Vatu-i-Ra Seascap . The ROV deployments were two hours in duration. Video-transects were recorded at the 11 investigated depths (black line). The video files were taken every minute along 10 minute periods (blue lines).

Appendix S2: Adapted classification categories based on a simplified scheme of CATAMI (Version 1.2) classification used to identify organisms to a morpho-family level

The follow categories were used to classify benthic biota at this study:

- Four major categories - Stony Corals, Black & Octocorals, Macroalgae, and Other Invertebrates

- Stony Corals two main divisions – *Acropora* and Non-*Acropora* (NA) – followed by seven subdivisions according to the morphology type – Branching, Digitate, Submassive, Massive, Table, Corymbose, and Encrusting.

- Black & Octocorals the same as CATAMI (Collaborative and Automated Tools for Analysis of Marine Imagery) Classification Scheme (Version 1- August 2013)

- Macroalgae four divisions - Turf Algae, Macroalgae, Crustose Coralline, and Articulated Calcareous

- Other Invertebrates eight main groups – Sponges/Ascidians, Bryozoans, Anemones, Bivalves, Urchins, Sea Cucumbers, Crinoids, and Hydroids

Appendix S1: Experimental design of ROV deployments at the four sites of Vatu-i-Ra Seascape

Appendix S3: Information of all taxa that were identified at genera level at the investigated sites

Identified Genera			
Depth	**Genera**	**Depth**	**Genera**
10	*Acropora, Chlorodesmis, Diploastrea, Halimeda, Favia, Favites, Leptoseris, Lobophytum, Merulina, Pachyseris, Pocillopora, Porites, Protopalythoa, Sarcophyton Sinularia, , Stylaster, Turbinaria, Tydemania, Trachyphyllia*	**60**	*Anthias, Halimeda, Heniochus, Leptoseris, Lutjanus, Pachyseris, Scleronephthya, Scolymia, Stylaster, Tubinaria*
20	*Acropora, Chlorodesmis , Diploastrea, Distichopora, Ellisela, Favia, Favites, Halimeda, Leptoseris, Lobophyton, Montastrea, Pachyseris, Protopalythoa, Pocillopora, Porites, Sarcophyton, Siphonogorgonia, Spondylus, Stylaster, Symphyllia, Tydemania, Turbinaria,*	**70**	*Echinophyllia, Epinephelus, Heniochus acuminatus, L.biguttatus, Naso, Pachyseris, Pomachantus, Stylaster,*
30	*Acropora, Capnella, Chlorodesmis, Favites, Fungia, Halimeda, Holothurian, Lobophyton, Mycedium, Pachyseris, Pavona, Pocillopora, Porites, Protopalythoa,*	**100**	*Dendronephthya, F. Nepthteidae , Heniochus, Lutjanus*

	Sarcophyton, Scolmya, Sinularia, Stylaster, Symphyllia,Tydemania		
40	*Acropora, Chlorodesmis, Ellisela, Fungia, Halimeda, Leptoseris, Lobophyton, Pachyseris, Plectropomus, Porites, Scleronephthya,Spondylus*	**115**	*Epinephelus, F. Nepthteidae , Scleronephyta*
50	*Cynarina, Echinophyllia, Ellisela, Halimeda, Stylaster*	**130**	*Epinephelus, F. Nepthteidae , Scleronephyta*

CONCLUSÃO GERAL

Através de uma abordagem que utiliza um esquema de identificação morfo-funcional hierárquico e com a utilização de um ROV para amostragem pode-se fazer uma caracterização geral representativa da comunidade epibentônica ao longo de recifes rasos e mesofóticos em recifes de corais de Vatu-i-Ra no Mar de Coral nas ilhas Fiji pela primeira vez. Demonstrou-se que os corais pétreos variam negativamente com a diminuição da zona fótica como o esperado. Foi detectado a presença desses organismos até os 130 m de profundidade. Octocorais e corais negros apresentam maior abundância em profundidades intermediárias (50-70m). Tipos morfológicos incrustantes foram identificados somente em recifes rasos, prevalecendo por toda zonação vertical a morfologia ramificada. Uma alta abundância de algas (>30%) foi encontrada em toda área investigada. As algas turf foram as mais abundantes seguidas pelas algas coralinas incrustantes. Esponjas e ascídias são o segundo grupo mais abundante da comunidade e também apresentaram variação direta em relação a profundidade, porém variam com a interação do tipo de substrato encontrado. Por fim, conclui-se que a combinação desse tipo de metodologia de identificação e o uso de dispositivos automatizados pode auxiliar para patamares de referência que contribuem para o conhecimento de ecossistemas recifais mesofóticos, e consequentemente proveem subsídios para a adequação de manejo e monitoramento de ambientes recifais como um todo.