A Rapid Biological Assessment Survey Of The Lau Seascape In Fiji

CONSERVATION INTERNATIONAL Fiji

by:
Semisi Meo, Mark Erdmann, Gerry Allen, Alexandra Dempsey, Schannel van Dijken, Doug Fenner, David Kline, Tiko Lesi, Daniela Schulman, Bridget Kennedy and Susana Tuisese.

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Amphiprion chrysopterus

Contents

Participants and authors

RAP Scientific Team

Gerry Allen, (Marine Fish)
Conservation International, Consultant
Australia

Alexandra Dempsey, (Marine Benthic)
Living Oceans Foundation
821 Chesapeake Avenue #3568
Annapolis, MD 21403

Schannel van Dijken, (Sea Cucumber)
Conservation International, Samoa
P. O. Box 2035
Apia, Samoa

Mark Erdmann, (Marine Fish)
Conservation International, Asia-Pacific
c/o Dean of Science
6th Floor Science Building, Building 302
23 Symonds St.
University of Auckland
Auckland 1010, New Zealand

Doug Fenner, (Marine Coral)
NOAA NMFS Office of Protected Resources
1315 East-West Highway
13th Floor
Silver Spring, MD 20910

David Kline, (Benthic, Marine Coral)
Smithsonian Tropical Research Institute
Apartado 0843-03092, Balboa
Republic of Panama

Semisi Meo, (Marine Fish)
Conservation International, Fiji
3 Ma'afu Street
Suva, Fiji

Ron Vave (Marine Coral)
University of Hawai'i at Manoa
Hawai'i Institute of Marine Biology
46-007 Lilipuna Rd
Kaneohe, HI 96744

Olive Andrews (Cetaceans, Mammals)
Conservation International
c/o Dean of Science
6th Floor Science Building, Building 302
23 Symonds St.
University of Auckland
Auckland 1010, New Zealand

Logistics Crew

Marika Buaserau (Medic)

Edgardo Ochoa (Marine Safety)
Conservation International

Katie Bryden (Photography)
Conservation International

Richard Sidey (Photography)

Tevita Vodivodi (Marine Fish)

Frank Hazelman (Marine Fish)

Volau Tiko (Sea Cucumber)

Seruqali Ledua (Tender captain)
Fisheries MRIS
Ministry of Fisheries and Forests (MFF)
PO Box 2218
Government Building
Suva, Fiji Islands

Viliame Tui (Compressor Operator)
Suva Scuba

Cultural Guides

Roko Josefa Cinavilakeba (Chief of Totoya)

Pacific Blue Foundation
P.O.B 13306, Suva.
Fiji Islands

Rusiate Misikivosa (Lau Provincial Office)

Donors

Matt Brooks & Pamela Rorke Levy

Greg Mitchell and the Pacific Blue Foundation.

Editors

Daniela J. Schulman

Bridget Kennedy

Organizational profiles

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Headquarter Office
2011 Crystal Drive, Suite 500
Arlington, VA 22202

T: (703) 341-2400
W: www.conservation.org

Fiji Office
3 Ma'afu Street
Suva, Fiji

T: +679 331 4593
W: www.conservation.org/places/fiji

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T: (808) 236-7401
W: www.himb.hawaii.edu

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Pacific Blue Foundation P.O.Box 2014
La Jolla, CA 92038

T: 679-839-0473
W: www.pacificbluefoundation.org

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INTRODUCTION

The Marine Rapid Assessment Program

The Marine Rapid Assessment Program conducts scientific surveys (MRAPs) to fill in data gaps on marine biodiversity in areas where data are lacking or biodiversity is under threat. Surveys provide data on select species of biological and commercial importance, as well as the health of the habitats sampled. Generally, in situ fieldwork, both underwater and on land, provides a snapshot status of the ecological threats and documents socioeconomic issues regarding marine resource use patterns. Scientists employ a rigorous scientific approach and methods, and consult with all local stakeholders, including government and non-governmental organizations.

The information obtained during the MRAP is analyzed, synthesized and geo-spatially mapped with other relevant and available data to: a) outline the composition of key ecological species and habitats within the region and recommended conservation strategies and activities (e.g. establishing locally managed marine areas) for mitigating threats to biodiversity (e.g. curtailing destructive fishing techniques); b) identify data gaps and topics for further study (e.g. stock assessments); and c) address questions regarding biodiversity and the design of marine protected areas.

Findings from MRAP surveys enable informed decision making, especially for the creation of marine managed and protected areas and implementation of other conservation tools. The surveys also provide an exchange and knowledge-sharing resource between national and international scientists to build capacity. Education and awareness on the importance of marine biodiversity and sustainable resource use are also raised as a result of MRAPs.

Description of MRAP survey sites

From 5–16 May 2017, the MRAP team surveyed along a 500 nautical mile (900 km) route, covering 28 sites (Table 1) over an estimated area of 27,520m2 (2.75 ha) in the Lau Group of the Fiji Islands (Figures 1 and 2). Fiji is an island nation and archipelago of over 330 islands in the South Pacific, of which approximately 106 are permanently inhabited (Neall and Trewick, 2008). Most of the islands of Fiji are surrounded by coral reefs, home to a great diversity of marine flora and fauna.

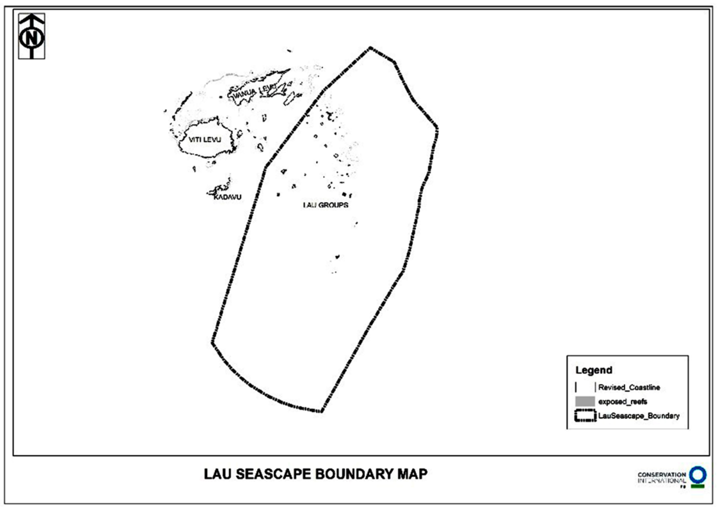

Figure 1. Site map showing the Lau Seascape

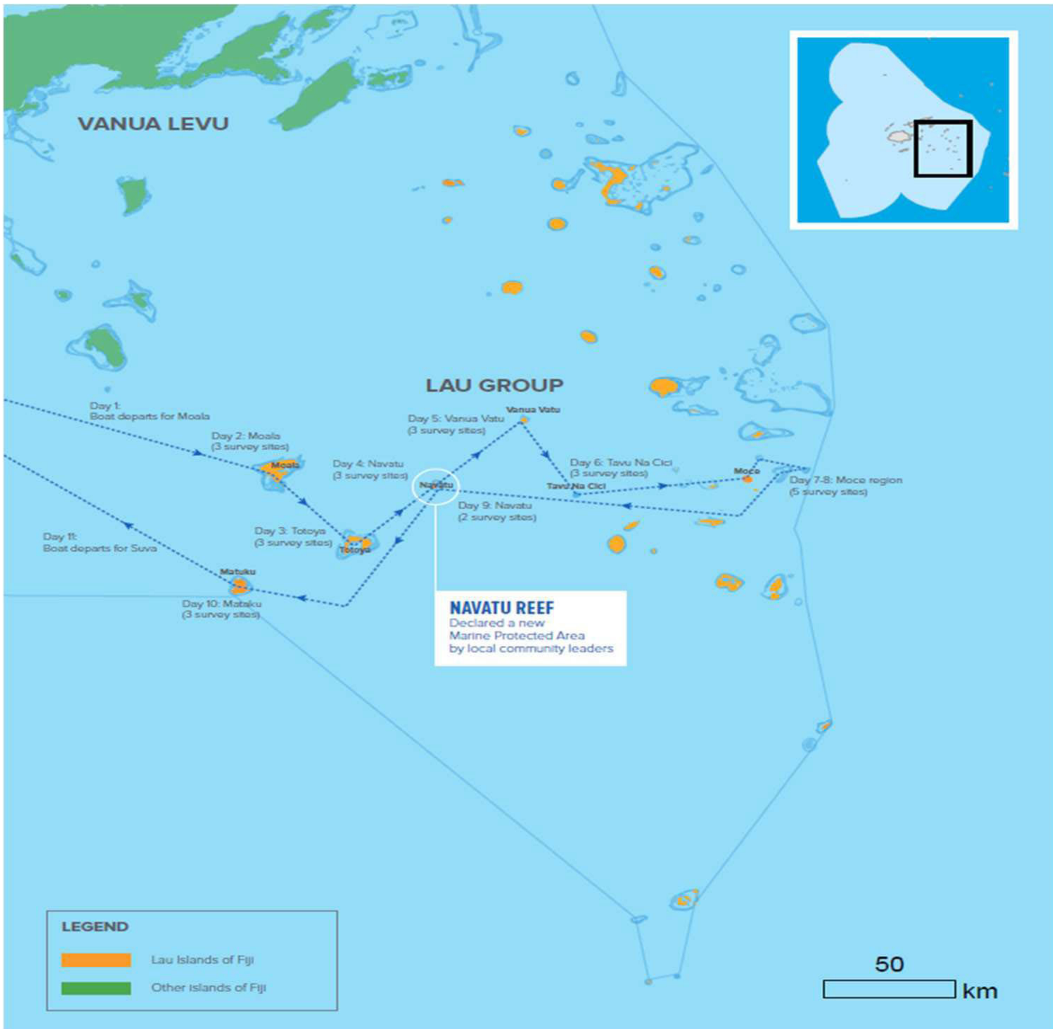

Figure 2: Map showing the route of the research vessel MV Sea Rakino. Photo: CI/MV Erdmann; Map: CI/ Cheryl Sekkappan.

Fiji's Lau Seascape, a group of 60 islands east of Viti Levu, is a mecca of biodiversity, identified as a hotspot for species richness (Selig et al. 2014; Trebilco et al. 2011; Tittensor, et al. 2010) and species endemism (Selig et al. 2014) (Figures 3a and 3b).

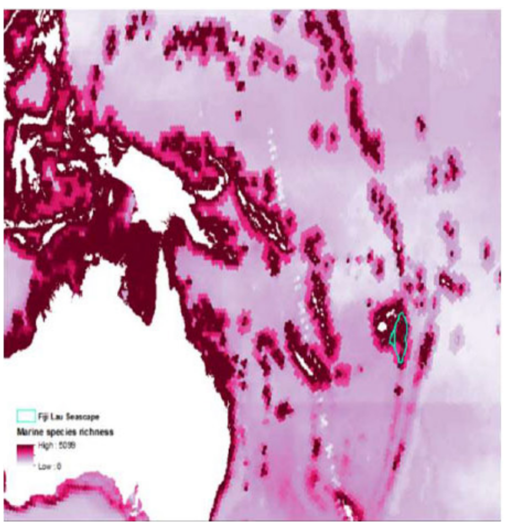

Figure 3a: Species richness (Selig, et al. 2014)

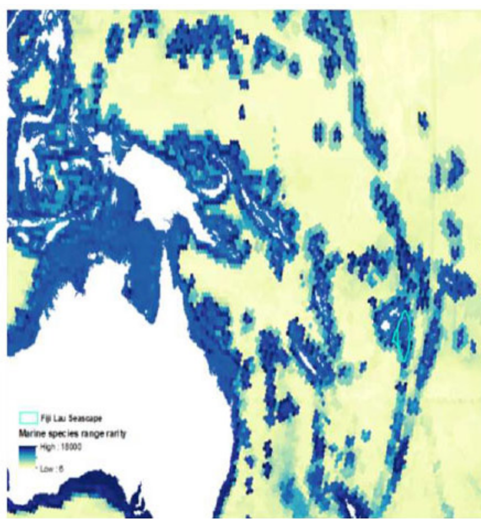

Figure 3b: Species endemism (Selig, et al. 2014)

In2003, southern Lau was declared one of Fiji's five globally significant marine ecoregions by a group of more than 80 scientific experts, community and government representatives convened by the World Wildlife Fund (WWF) (Nair et al. 2004). Lau's 9,602 inhabitants depend on the continued health of the islands, coastal and ocean ecosystems for food, livelihoods and climate resilience (Fiji Population and Housing Census 2017). This MRAP survey recognizes the Lau Seascape Initiative, designed in consultation with local communities, government officials and technical experts, as a high priority area for conservation.

Table 1. Summary of 28 surveyed sites on Lau Seascape MRAP expedition in May 2017

Site no.	Site code	Date surveyed	Island name	Location name	Coordinates	Reef zone	Depth range (m)
1	ML01	5 May 17	Moala	Moala NE Pinnacles	18° 32.254' S, 179° 55.721' E	Lagoon	1–18
2	ML02	5 May 17	Moala	Moala NE Lagoon	18° 35.218' S, 179° 57.169' E	Lagoon	1–40
3	ML03	5 May 17	Moala	Moala E Outer Reef	18° 39.710' S, 179° 54.936' E	Fore reef slope	1–40
4	TY01	6 May 17	Totoya	Totoya Eastern Lagoon	18° 57.771' S, 179° 46.399' E	Lagoon	1–15
5	TY02	6 May 17	Totoya	Totoya Inner Channel Pass	18° 59.848' S, 179° 50.849' E	Lagoon	1–25
6	TY03	6 May 17	Totoya	Totoya Western Channel	18° 57.760' S, 179° 54.215' E	Lagoon	1–30
7	NV01	7 May 17	Navatu	Navatu Outer West	18° 41.201' S, 179° 35.379' E	Fore reef slope	1–50
8	NV02	7 May 17	Navatu	Navatu North Channel Pass	18° 39.445' S, 179° 34.885' E	Fore reef slope	1–30
9	NV03	7 May 17	Navatu	Navatu North Lagoon	18° 39.624' S, 179° 34.587' E	Lagoon	1–12
10	VT01	8 May 17	Vauna Vatu	Vanua Vatu North	18° 20.909' S, 179° 16.294' E	Fore reef slope	1–45
11	VT02	8 May 17	Vauna Vatu	Vanua Vatu West	18° 22.367' S, 179° 17.214' E	Fore reef slope	1–46
12	VT03	8 May 17	Vauna Vatu	Vanua Vatu North Inner Channel	18° 21.644' S, 179° 17.198' E	Fore reef slope	1–12
13	TS01	9 May 17	Tavunasici	Tavunasici North	18° 42.702' S, 179° 05.398' E	Fore reef slope	1–45
14	TS02	9 May 17	Tavunasici	Tavunasici West	18° 43.030' S, 179° 05.985' E	Fore reef slope	1–45
15	TS03	9 May 17	Tavunasici	Tavunasici Channel	18° 42.929' S, 179° 05.672' E	Fore reef slope	1–40
16	OL01	10 May 17	Olorua	Olorua North	18° 35.631' S, 178° 45.823' E	Fore reef slope	1–20
17	OL02	10 May 17	Olorua	Olorua South	18° 37.364' S, 178° 45.236' E	Fore reef slope	1–22
18	OL03	10 May 17	Olorua	Olorua West	18° 33.244' S, 178° 46.132' E	Fore reef slope	1–20
19	MC01	11 May 17	Cakau LekaLeka	Cakau LekaLeka	18° 32.971' S, 178° 28.825' E	Fore reef slope	1–50
20	MC02	11 May 17	Cakau Vate	Cakau Vate	18° 36.440' S, 178° 19.421' E	Fore reef slope	1–50

21	MC03	12 May 17	Cakau Mota	Cakau Mota	18° 36.979' S, 179° 25.459' E	Fore reef slope	1–45
22	MC04	12 May 17	Karoni	Karoni	18° 41.345' S, 179° 28.324' E	Fore reef slope	1–40
23	MC05	12 May 17	Karoni	Karoni Lagoon	18° 41.756' S, 179° 28.744' E	Lagoon	1–10
24	NV04	13 May 17	Navatu	Navatu SW	18° 41.725' S, 179° 35.153' E	Fore reef slope	1–28
25	NV05	13 May 17	Navatu	Navatu West 2	18° 41.138' S, 179° 35.351' E	Fore reef slope	1–10
26	MT01	14 May 17	Matuku	Matuku West Lagoon	19° 09.115' S, 179° 44.732' E	Island slope reef	1–28
27	MT02	14 May 17	Matuku	Matuku West Channel	19° 09.378' S, 179° 43.909' E	Fore reef slope	1–10
28	MT03	14 May 17	Matuku	Matuku East Lagoon	19° 08.805' S, 179° 47.345' E	Lagoon	1–30

Reasons for the MRAP survey

Global analyses of marine biodiversity consistently place the Lau archipelago among the highest priorities for conservation, as a hotspot for species richness (Selig et al. 2014; Trebilco et al. 2011; Tittensor et al. 2010) and species endemism (Selig et al. 2014). Tittensor's examination of global patterns and predictors of marine species richness across 13 major species groups, ranging from zooplankton to marine mammals, indicates that the Western Pacific contains the world's greatest diversity of coastal species, while oceanic groups consistently peak across broad mid-latitudinal bands in all oceans. In 2003, southern Lau was declared one of Fiji's five globally significant marine ecoregions by a group of more than 80 scientific experts, community and government representatives convened by the World Wildlife Fund (Nair et al. 2004). Southern Lau is also categorized as an ecologically or biologically significant area, with key biodiversity areas and important bird areas in both northern and southern Lau (Government of Fiji 2017). Lau's inhabitants depend on healthy island, coastal and ocean ecosystems for food, livelihoods and climate resilience.

Indigenous communities across the Pacific region have strong cultural and economic ties to the ocean and its resources, as voyagers, fishers and island dwellers. Lauans possess a rich and intact cultural heritage and boast 2,700 km2 of customary fishing areas *(iqoliqoli)* and 52 Fiji Locally Managed Marine Areas (FLMMA). Outside these areas, local subsistence fishers normally use spears, handlines or small nets, and often walk on the shallow reef tops.

In the Pacific region, land and land-based resources belong to indigenous peoples and local communities – in Fiji, over 87% of land is owned and managed by indigenous peoples, while the ocean belongs to the state. Despite this legal designation of ocean rights, governments and other stakeholders recognize that customary stewardship of the ocean has existed for centuries, grounded in strong cultural links with the ocean, including traditional ocean voyaging.

Indigenous communities in Lau manage their coastal fishing grounds, iqoliqoli, through establishment of tabu areas, traditional temporary closures made for cultural or ecological reasons, such as maintaining fish stocks. They form modern-day nearshore marine protected areas (MPAs). This project provided primary support to the *Vanua o Lau* and worked collaboratively with the Fiji Ministry of iTaukei Affairs and its regional subsidiary, the Lau Provincial Council, and the iTaukei Affairs Board to support implementation of the Lau Seascape Strategy.

The precise boundaries of Fiji's Lau Seascape were designed through a consultative process with local communities, government officials and technical experts (Figure 2). The Seascape's 335,000 km2 area comprises *iqoliqoli* and the archipelagic waters of the Lau Province, including 60 islands, half of which are home to approximately 9,602 people (Fiji Population and Housing Census 2017). The primary objective of the MRAP survey was to assess the status and biodiversity of the reefs of the southern Lau Island group in order to help inform the management of the 335,000 km2 Lau Seascape.

Major results

Benthic cover – The sites surveyed were dominated by pavement (range 48.0–64.9%), with relatively high living coral cover (range 20.2–34.3%) and low coverage of sand (range 2.7–11.9%), rubble (range 2.3–4.0%) and recently dead coral (range 0.0–0.1%; Chapter 1, Table 1). These benthic coverage results suggest that all the Lau reefs surveyed had healthy benthic communities, with almost no recently dead coral, and that there was no bleaching-related mortality associated with the 2016 global bleaching event. The species recorded are shown in Table 2 and species of conservation concern documented during the survey are shown in Table 3.

Reef coral – 206 hard coral species were recorded, including a number of new records for Fiji and 10–20 species that have yet to be classified. Reef health was highly variable. Some reefs were stunning, with over 80% live hard coral cover, while other reefs were well under 20% live hard coral and showed signs of past mortality from bleaching and crown-of-thorns starfish outbreaks. Some reefs showed extensive overgrowth by cyanobacteria, perhaps precipitated by the rampant overexploitation of sea cucumbers which was evident on all sites.

Coral reef fish – Over the course of the survey 527 reef fish species were recorded, including at least six new species and over 50 new records for Fijian waters. Gobies (Gobiidae), wrasses (Labridae) and damselfishes (Pomacentridae) are the dominant family groups in the Lau Archipelago in both number of species (99, 77, and 58 respectively) and number of individuals. Low numbers of sharks, large groupers (Epinephelus), Napoleon wrasse (Cheilinus undulatus) and bumphead parrotfish (Bolbometopon muricatum) were observed during the survey, an indication of over-fishing. Importantly, reef sharks were observed at 26 of the 28 survey sites. While never observed in large numbers, their presence is a good sign that Lau's reef ecosystems are still intact and should rebound quickly if carefully managed. Commercially important reef fish, such as grouper and snapper, were ever-present but many reefs showed significant signs of overfishing. A mixture of remote reefs and populated islands showed the highest biomass of food fish.

Sea cucumber – A total of 63 individual sea cucumber belonging to 15 species was recorded over an estimated area of 27,520 m2 (2.75 ha) in this assessment. Among sites, Navatu and Tavunasici had the highest number of sea cucumber recorded. Five species not observed in a 2013 Lau Group assessment were recorded, two of which were not recorded in any Fijian waters in 2013. On the other hand, three species observed in 2013 within Lau Group were not observed in this assessment. Furthermore, four species known to be present in Fiji's waters that were not observed in 2013 were also not observed in 2017. Tiger fish (B. argus) and amber fish (T.anax) were the most frequently encountered species from the assessment, with densities of about five individuals per hectare. When compared with regional reference densities, all sea cucumber species recorded in the Lau Group in this assessment are of low densities.

Table 2. Species recorded during Lau Seascape MRAP survey, May 2017

Site no.	Island name	Reef corals	Coral fish	Sea cucumber
1	Moala	53	125	0
2	Moala	94	134	0
3	Moala	69	160	0
4	Totoya	83	131	6 *(all 3 sites)
5	Totoya	81	172	*
6	Totoya	62	154	*
7	Navatu	84	188	15 **(all 3 sites)
8	Navatu	66	173	**
9	Navatu	10	113	**
10	Vauna Vatu	83	150	5 †(all 3 sites)
11	Vauna Vatu	71	179	†
12	Vauna Vatu	85	123	†

13	Tavunasici	64	179	12 ††(all 3 sites)
14	Tavunasici	-	179	††
15	Tavunasici	28	153	††
16	Olorua	74	146	4 *(all 3 sites)
17	Olorua	52	142	*
18	Olorua	53	141	*
19	Cakau Lekaleka	73	170	5
20	Cakau Vate	75	183	0
21	Cakau Mota	65	197	-
22	Karoni	67	173	8 **(both sites)
23	Karoni	52	50	**
24	Navatu Reef	72	-	2 †(both sites)
25	Navatu Reef	-	-	†
26	Matuku	42	195	6 ††(all 3 sites)
27	Matuku	70	207	††
28	Matuku	56	136	††
Potentially new to science:		15	6	
Total species count:		206	527	15

Table 3. Species of conservation concern documented during Lau Seascape MRAP survey, May 2017. VU – Vulnerable; EN – Endangered; NT – Near threatened

Group	Species	IUCN Category
Reef corals	Pocillopora danae	VU
	Montipora caliculata	VU
	Isopora crateriformis	VU
	Isopora cuneata	VU
	Acropora aculeus	VU
	Acropora anthocercis	VU
	Acropora carolineana	VU
	Acropora echinata	VU
	Acropora globiceps	VU
	Acropora paniculata	VU
	Acopora polystoma	VU
	Acropora retusa	VU
	Acropora speciosa	VU
	Acropora verweyi	VU
	Astreopora cucullata	VU
	Euphyllia cristata	VU
	Euphyllia paradivisa	VU
	Galaxea astreata	VU
	Pavona cactus	VU
	Pavona cf. diffluens	VU
	Pavona venosa	VU
	Leptoseris incrustans	VU
	Acanthastrea brevis	VU
	Acanthastrea hemprichii	VU
	Acanthastrea ishigakiensis	VU

	Symphyllia hassi	VU
	Porites horizontallata	VU
	Porites nigrescens	VU
	Turbinaria peltata	VU
	Turbinaria reniformis	VU
	Turbinaria stellata	VU
Coral fish	Carcharhinus albimarginatus	VU
	Carcharhinus melanopterus	VU
	Triaenodon obesus	VU
	Taeniura meyeni	VU
	Epinephelus polyphekadion	VU
	Bolbometopon muricatum	VU
	Oxymonacanthus longirostris	VU
	Aetobatus narinari	NT
	Chaetodon trifascialis	NT
	Bryaninops natans	NT
	Scomberomorus commerson	NT
	Siganus uspi	NT
	Carcharhinus amblyrhynchos	EN
	Cheilinus undulatus	EN
Sea cucumbers	Actinopyga mauritiana	VU
	Actinopyga miliaris	VU
	Holothuria fuscogilva	VU
	Holothuria whitmaei	EN
	Thelenota ananas	EN

Conservation recommendations

- **Establish a pathway for sustainable tourism together with local communities and in alignment with ecological and social carrying capacity:** The coral reefs of the Lau Islands are diverse and intact (Figure 4), and offer a unique tourism experience to recreational divers. If practiced sustainably, diving offers one of the most environmentally friendly uses of coral reefs, particularly when divers effectively control their buoyancy, avoid physical contact with pristine reefs, and even participate in reef restoration activities. Other economic sectors have a noticeably greater impact on reef health, such as modern and commercial agriculture from which nutrient run-off of fertilizers and pesticides can cause reef degradation. In addition, many of Lau's communities reject traditional tourism approaches, such as resort tourism, in order to protect their cultural integrity, heritage and traditional way of life. It is important that local communities are able to decide whether they want additional development and ecotourism, and determine what that entails. Dive tourism offers a more sustainable economic pathway and alternative to resort tourism, with less cultural and ecological impact, however, with less revenue potential.

- **Establish marine protected areas:** Establish new protections in areas with high species richness, coral cover and fish abundance. Social acceptance is a critically important factor for the success of protected areas, and ensuring alignment with community and government priorities. As an example, on the fourth day of the trip, CI and partners visited Navatu Reef, a remote atoll that is under the customary tenure of Vanuavatu. The reef was particularly stunning and new findings were documents from the survey. Following the survey, the traditional leaders of Vanuavatu declared the Navatu Reef atoll a marine protected area (MPA)

- **Establish species bans and size restrictions for fishing in the Lau Seascape:** One of the most effective tools in coastal fisheries management and coastal protection, is establishment of Tabu Areas. Establishing species bans (could be temporal) and size restrictions help to protect vulnerable fish species within coastal fishing areas.

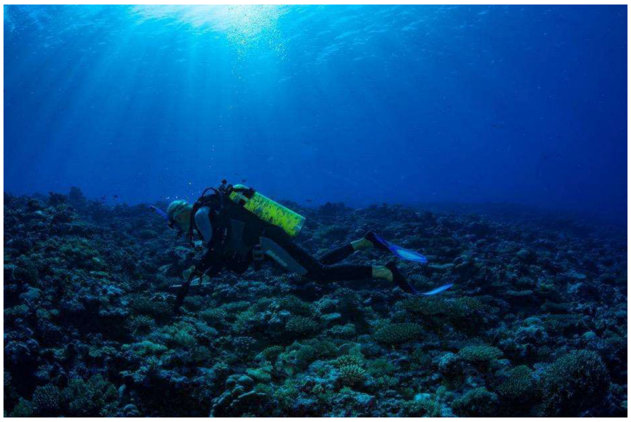

Figure 4. Doug Fenner surveys hard coral diversity on Navatu reef. Photo: CI/MV Erdmann

- **Establish a coral reef monitoring program:** Additional support and effort is needed to monitor the health of Lau's reefs over time. Critically, a monitoring program should be established to identify the most prominent threats to coral reef ecosystems, assess reef health over time, and proposed alternative solutions to improve reef health and functioning.

CI looks forward to working closely with the government, traditional communities of the Lau Seascape and additional partners and stakeholder to realize a holistic vision of sustainability and economic development for the people of Lau.

Efforts to date

In 2017, the provincial chiefs of Lau made a commitment for the Lau Group to become organic islands. Building on these commitments, the Lau Seascape is now a multi-partner initiative driven by CI and comprised of community and indigenous representatives, as well as private sector and NGO stakeholders, grounded in a joint memorandum of understanding (MoU). At the time of this publication, six partners have signed the MoU – the Coral Reef Alliance, the Pacific Blue Foundation, Loving Islands, Vatuvara Foundation, the Fiji Locally Managed Marine Area Network and USP – and other organisations are interested in joining.

Under the Lau Seascape Initiative, CI is organizing partners and national stakeholders around a shared vision for Lau's Islands that links sustainable development with conservation efforts. In March 2018, CI led the development of a 10-year strategy for the Lau Seascape initiative, together with MoU and government partners. This strategy was designed using the open standards for conservation methodology (Conservation Measures Partnership, 2013) and Miradi software (www.miradi.org). Through this process, the Lau Seascape stakeholders articulated the need for investment in tourism infrastructure, such as moorings for yachts that regularly visit the islands, sustainable agriculture and livelihood diversification, renewable energy, coastal and nearshore fisheries management, information and communications frameworks, and many other critical support areas. Stakeholders also prioritized a sequenced investment pathway to direct allocation of resources at scale across the islands. CI and partners are also working closely with the Lau Provincial Office under the Ministry of iTaukei Affairs, tasked with serving and representing Fiji's indigenous iTaukei communities, to ensure alignment of activities with their annual work plan.

At the national level, supporting sustainable development in Lau is a priority of the Fiji Government, the Ministry of Fisheries and the Department of Environment, the latter having provided a letter of support for the initiative. In June 2017, at the United Nations Oceans Conference for Sustainable Development of Goal 14, the Fiji Government declared the Lau Seascape Initiative as one of 17 voluntary commitments. Together with other area-based protection and management targets for Fiji. Covering the largest maritime province in the country, the Lau Seascape Initiative will help Fiji achieve its commitment to the United Nations Committee on Biological Diversity to protect 30% of its seas by 2020, as well as Fiji National Ocean Policy published in 2021 and other commitments to conserve 10% of inshore areas. In addition, CI is serving as a member of the Fiji Government Marine Protected Area Technical Committee, aimed at increasing the number of offshore and inshore MPAs, to advance MPA development in Lau. The Lau Seascape initiative also aligns with the national Green Growth Framework (Thematic Areas 3 and 6), as well as sectoral policies in fisheries, land use, forests, integrated coastal management and sustainable development.

Equipped with a 10-year strategy, community leadership, government endorsement and strong partnership approach, the Lau Seascape now critically needs resource mobilization to ensure national goals and commitments translate to real and sustained conservation impacts.

Chapter 1: Benthic survey report

Alexandra Dempsey and David I. Kline

Abstract

The sites surveyed were dominated by pavement (range 48.0–64.9%), with relatively high living coral cover (range 20.2–34.3%) and low coverage of sand (range 2.7–11.9%), rubble (range 2.3–4.0%) and recently dead coral (range 0.0–0.1%; Table 1). These benthic coverage results suggest that all the Lau reefs surveyed had healthy benthic communities with almost no recently dead coral, and that there was no bleaching-related mortality associated with the 2016 global bleaching event.

Introduction

Coral reef benthic communities are critical for maintaining the structural integrity of a reef ecosystem. They are the basis for many marine food webs, and provide other important ecological services (Cinner et al. 2006). Regular monitoring and studies to understand the community structure and condition of benthic habitats are critical to determine the effects of stressors on these vulnerable ecosystems. Cyclones, bleaching events, ocean acidification, overfishing, and outbreaks of coral predators are hypothesized to be the main stressors responsible for the observed changes in the composition and structure of benthic communities in Lau Province, Fiji (Cumming et al. 2002, Dulvy et al. 2004).

The Lau Islands form one of 14 provinces in Fiji and are located in the South Pacific Ocean, east of the Koro Sea and separated from the Fiji Platform by the Nanuku Channel. While most of the northern islands are high and volcanic in origin, those in the south are a mix of extinct oceanic volcanoes and low-lying carbonate islands (Bruckner et al. 2016). These include several atolls and extensive fringing reef systems that enclose a few smaller islands. These small, remote islands are far from the tourist centres of Fiji, and are home to small villages of Pacific Islanders run by traditional leaders. Approximately 30 islands in the Lau Province are sparsely populated. These communities rely heavily on the coral reef ecosystem for their livelihood, mainly through engaging in artisanal and subsistence fishing. Although human populations are relatively low, pollution and fishing have contributed to the decline of these reef systems.

While less historic data are available on the condition of coral reefs in Lau Province, these reefs have experienced large declines in coral cover since 1998. Impacts from mass bleaching events have been documented throughout Fiji as global bleaching events have become more severe and frequent (Hughes et al 2017). Coral reef benthic studies in Lau Province have previously been conducted by Dulvy et al. (2004), Turner et al. (2007), Wilson et al. (2008), and Bruckner et al. (2013).

This study, spearheaded by Conservation International, focuses on the evaluation of the benthic community structure and composition, as well as documenting impacts of broad scale disturbances and patterns of recovery. The 198 benthic surveys conducted in 2017 for the Marine Rapid Assessment Program (MRAP) of the Lau Seascape initiative in the Eastern Fiji Archipelago were designed to provide relevant information on the changes to benthic communities that occurred since the early 2000s. The MRAP surveys provide data on select species of biological and commercial importance and descriptions of the status of the reef's habitats sampled. The benthic coverage results from the 2017 MRAP suggest that the Lau reefs surveyed had largely healthy benthic communities with almost no recently dead coral or bleaching-related mortality associated with the 2016 global bleaching event.

Methods

The cover of major functional groups was assessed along 10 m transects using recorded observations and/or photographic assessments. The cover included: corals identified to genus, sponges, other invertebrates, and six groups of algae – macroalgae, crustose coralline algae, erect coralline algae, fine turfs, turf algae with sediment and cyanobacteria, and substrate type (hardground, sand, mud, rubble, recently dead coral, bleached coral, live coral). Recorded observations involved a point intercept method, whereas the organism and substrate were identified every 10 cm along a 10 m transect (total 100 points/transect), with a minimum of six transects examined per location. When possible, surveys were completed at 20, 15, and 10 m depth.

Photographic assessment

A 10 m long transect tape was extended along depth contours at 20, 15, and 10 m depth. Continuous digital still photographs were taken of the reef substrate from a height of approximately 0.6-0.75 metres above the substrate, using a one-metre bar divided into 10 cm increments placed perpendicular to the transect tape as a scale bar. Approximately 10 photographs were taken per depth. Images were downloaded onto a computer, and benthic community composition, coral cover and cover of other organisms and substrate type were analyzed using Coral Point Count with Excel extensions (CPCe) software developed by the National Coral Reef Institute. Cover was determined by recording the benthic attribute located directly below random points (50 points per photograph). At each location, three replicate reef sites were chosen, and benthic coverage data represents data averaged across the three reef sites. Three depths were measured per site and approximately 90 photos with 4,500 annotations were taken per location.

Key benthic categories

C= live coral, **DC**= dead coral, **P**= pavement, **R**= rubble, **S**= sand, **RD**= recently dead coral

All values are presented as % cover ± standard error.

Results

Site descriptions and benthic coverage

I. Moala reefs

(Note: the abbreviation in parentheses after the site name is the unique site code.)

Moala NE Pinnacles (ML01). This site was at the NE corner of the island and included relatively protected reef pinnacles rising up from 15–18 m depth of the sea floor **(Fig. 5A)**. It had relatively low live coral cover, with quite a bit of macroalgal and cyanobacteria cover, and a fair bit of dead standing coral, possibly due to prior disease or bleaching events. The site is a protected submerged patch reef in the lagoon. Cyanobacteria were abundant and often smothered live corals **(Fig. 5B)**. The site had relatively low living coral cover with many dead table corals still in standing growth position **(Fig. 5C, 4)**.

A) B) C)

Figure 5: Photographs of Moala NE Pinacles. A) shows the vertical profile of the reef. B) Cyanobacteria overgrowing corals. C) Dead table corals in standing growth position.

Moala NE Lagoon (ML02). This site was a series of patch reefs with a steep drop-off around the patch reefs to about 30 m, with a gradual gradation into sand to at least 45 m depth. It had 15–20% live coral cover, significant macroalgal cover and also a fair bit of dead standing coral. One crown-of-thorns starfish was observed feeding in the shallows (>3 m). The site is a protected submerged patch reef in the lagoon with very low visibility. The site had a higher biodiversity of corals but with less rugosity. Coral cover was still below average **(Fig. 8)**. Large branching corals were common on the sand flats and looked healthy **(Fig. 6B)**. Much fewer cyanobacteria were observed than in Moala NE Pinnacles. There was a particularly high abundance of non-colonial, free living Fungid corals **(Fig. 6A)**.

A) B)

Figure 6: Photographs of Moala NE Lagoon. A) shows a typical reef in the lagoon with the highly abundant non-colonial, Fungia corals shown with white arrows. B) Large branching Acropora colony growing on the sand flats.

Moala E. Outer Reef (ML03). This reef site had a more typical outer fringing reef ecosystem, with some spur and groove development in the wave-washed shallows and mostly small colonies (less than 6 cm in diameter), possibly indicating a disturbance event in the last five years **(Fig. 7A).** There was a relatively steep drop-off to 35 m, and then moderate grade into the depths, with scattered bommies. One crown-of-thorns starfish was observed feeding on corals at about 6 m depth. The fore reef site on the point of the channel was emergent, with some protection from wind and wave action. The emergent site had more complex reef morphology than previous sites **(Fig. 7B)**. Crustose coralline algae (CCA) and recruitment at the site were common, but large colonies of leather corals were also observed. There was a high diversity of Acropora corals at the site **(Fig. 7C)**. Fore reef communities often had a barrier reef with a reef flat leading to a series of pinnacles that drop near vertically to 15–20 m depth, followed by a more gradual slope. The walls and pinnacle faces often had undercut ledges and small caves.

A) B) C)

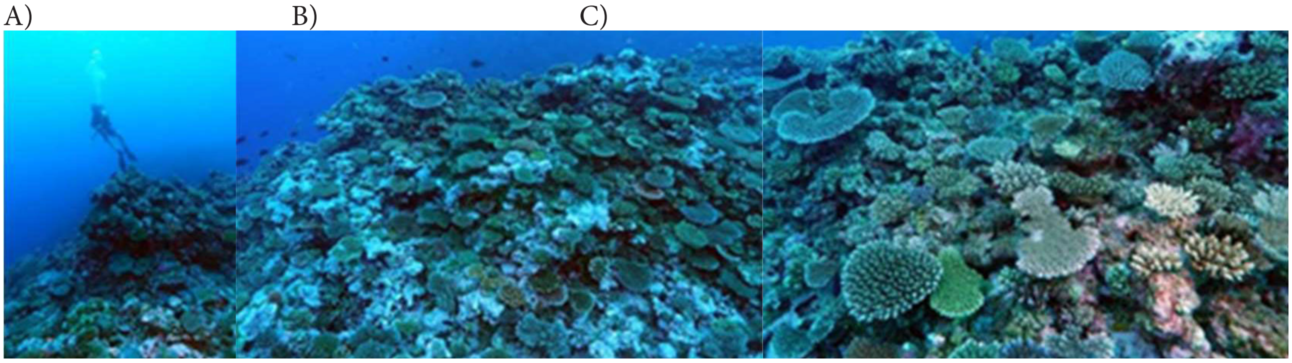

Figure 7: Photographs of Moala E outer reef. A) shows a typical shallow reef with spur and groove development and small coral colonies. B) Fore reef site, showing more structural complexity and C) a high diversity of Acropora species.

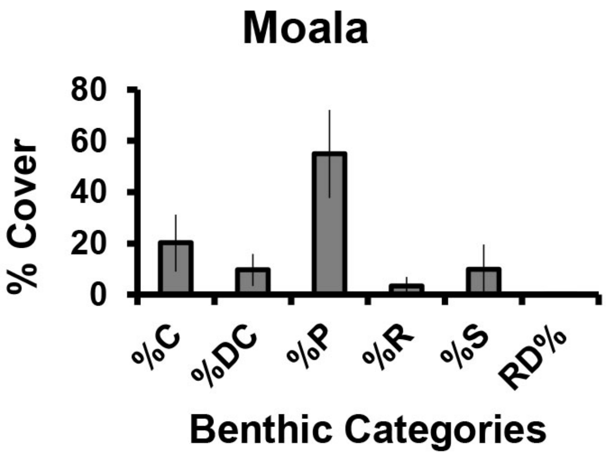

Figure 8: Average benthic coverage of the Moala NE Pinnacles, NE Lagoon site and Moala E. Outer reef sites. C = live coral, DC = dead coral, P = pavement, R = rubble, S = sand, RD = recently dead coral. All data are presented as percentage cover +/- standard error.

Benthic coverage Moala Reefs: The Moala reefs were dominated by pavement (55.0% ± 17.2%), with relatively high living coral cover (20.2% ± 11.1%), intermediate dead coral (9.6% ± 6.3%), and low rubble (3.4% ± 3.6%), sand (9.7% ± 9.8%) and recently dead coral (0.0% ± 0.01%) **(Fig. 8)**.

II. Totoya reefs

Totoya Eastern Lagoon (TY01J. The site is a protected, diverse submerged patch reef in a lagoon, with relatively high live coral cover **(Fig. 9)**. Two crown-of-thorns starfish were observed feeding on corals at about 6 m. Partial mortality was observed on many corals and cyanobacteria were common on recently dead corals. Corallivore lesions/scars were common, but no active feeding was observed. Vertical surfaces often had a rich plating coral community dominated by *Pachyseris*, *Merulina*, *Echinopora*, *Turbinaria*, *Montipora* and *Echinophyllia*, intermixed with soft corals, while the bases of some pinnacles had extensive assemblages of plating and foliaceous coral.

A) B) C)

Figure 9: Photographs of Totoya Eastern Lagoon. A) shows a typical shallow submerged patch reef; B) high coral coverage found on the patch reefs; and C) submerged patch reef starting at about 6 m depth.

Totoya Inner Channel Pass (TY02). This is a diverse and healthy fringing fore reef site that was emergent with full exposure to wind and wave action. Upwards of 75% live hard coral cover was observed in the shallows, with lots of big old colonies (some over 10 m across) **(Fig. 10)**. There was abundant CCA with smaller juvenile *Acropora* and *Pocillopora* colonies. There was also an abundance of encrusting *Millerpora* fire coral colonies. Leather coral *Lobophyton* and Sacrophyton were also common. Large *Turbinaria* colonies were found in the sand grooves **(Fig. 10A)**. Cyanobacteria were observed in higher concentrations on large dead branching corals. Shallow reef communities and the upper surfaces of pinnacles that were damaged or degraded had large mats of leather corals, and several deep reef communities were dominated by carpets of *Xenia* **(Fig 10B)**.

A) B)

Figure 10: Photographs of Totoya Inner Channel Pass. A) shows a large Turbinaria colony that was over 10 m in diameter; B) shallow reef with high coral coverage and diversity

Totoya Western Channel (TY03). There is exaggerated spur and groove formations on the southern side of the western channel, with 30–40% live cover on the spurs and rubble/sand in grooves. There is a moderate slope to at least 35 m. and a fringing fore reef site that was emergent with full exposure to wind and wave action **(Fig. 11A)**. Many dead corals were observed in standing growth form that had been covered in cyanobacteria. CCA was common. There were table *Acropora* colonies over a metre in diameter **(Fig. 11B)**. A lot of coral partial mortality was observed that was not consistent with crown-of-thorns or *Culcita* cushion star corallivory. Damselfish lawns were common. Large *Echinpora*, *Merulina*, and *Isopora* coral colonies were observed. Encrusting *Hydnophora* coral colonies were present and looked healthy. This fore reef community often had a barrier reef with a reef flat leading to a series of pinnacles that drop near vertically to 15–20 m depth, followed by a more gradual slope. The walls and pinnacle faces often had undercut ledges and small caves.

A) B)

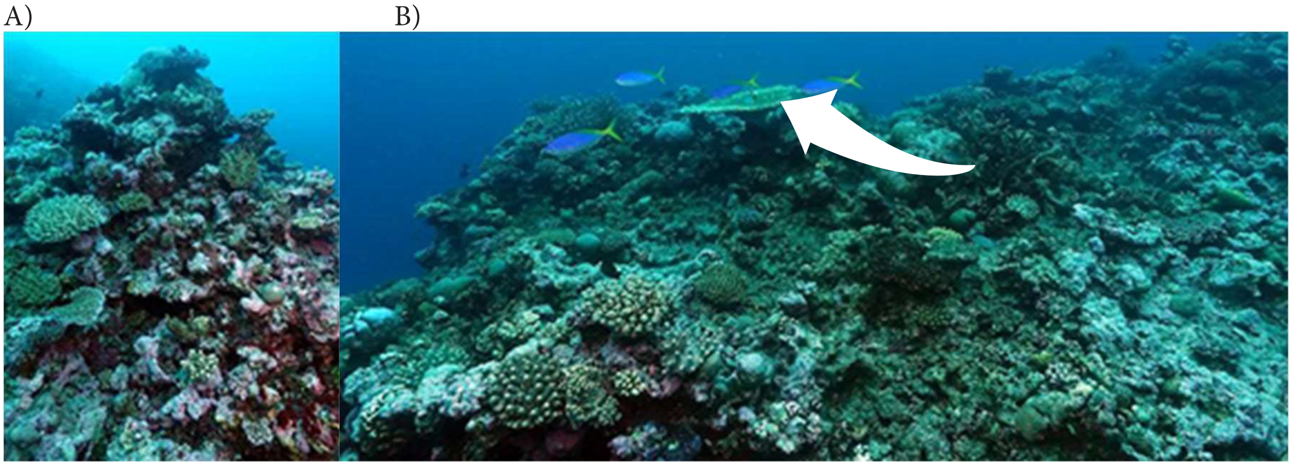

Figure 11: Photographs of Totoya Western Channel. A) shows a typical reef spur with relatively high coral and CCA coverage. B) Typical reef with relatively high coral coverage that included large table Acropora colonies shown with a white arrow, along with dead corals in standing growth form.

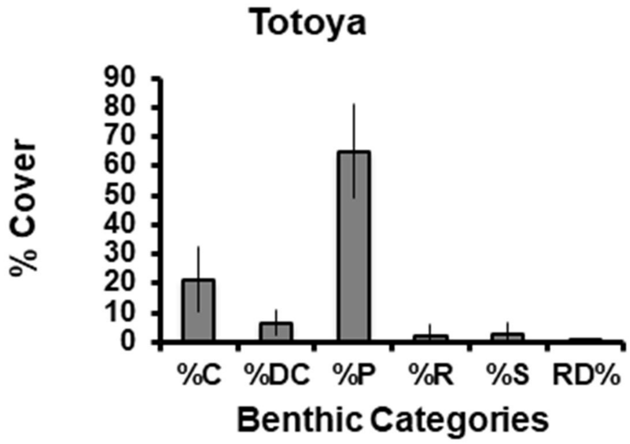

Figure 12: Average benthic cover of the Totoya Eastern lagoon, Inner Channel Pass, and Western Channel reef sites. C = live coral, DC = dead coral, P = pavement, R = rubble, S = sand, RD = recently dead coral. All data are presented as percentage cover +/- standard error.

Totoya benthic summary: The Totoya reefs were dominated by pavement (64.9% ± 16.0%), with relatively high living coral cover (21.3% ± 11.2%), and low dead coral (6.5% ± 4.3%), rubble (2.3% ± 3.6%), sand (2.9 % ± 4.1%) and recently dead coral (0.0% ± 0.0%) **(Fig. 12)**.

III. Navatu Reefs

Navatu Outer West (NV01). This reef site had a relatively healthy reef flat slope to about 4 m, then a steep drop to 14 m **(Fig. 13A)**, then a small plateau before a very steep slope into the depths. This site has diverse and high cover coral assemblages, with upwards of 75% live hard coral cover **(Fig. 13)**. The fringing fore reef site was emergent, with full exposure to wind and wave action. Shallow water areas had a well-developed zone, consisting of multiple canopy layers constructed of table *Acroporids* **(Fig 13BCD)**. Gently sloping surfaces, especially at the edge of the vertical wall, often had a rich branching coral community consisting of thickets of staghorn and bottlebrush *Acroporids*, *Pocillopora*, *Hydnophora*, *Stylophora*, *Seriatopora* and other taxa. Vertical surfaces often had a rich plating coral community dominated by *Pachyseris*, *Merulina*, *Echinopora*, *Turbinaria*, and *Montipora* coral genera.

A) *B)* *C)* *D)*

Figure 13: Photographs of Navatu Outer West. A) shows the reef flat at around 4 m with a steep drop to 14 m. B) shows healthy reef flat slope at around 4 m depth with high coral coverage and high numbers of table Acroporids. C) and D) show the high diversity and high structural complexity of reefs on the reef flat.

Navatu North Channel Pass (NV02). This reef site had a healthy reef flat with some spur and groove formation and numerous old *Porites* colonies. There was a drop-off to 20 m depth, where there was a current-swept sand plain, with a few isolated patch reefs at 25–30 m depth. This site had high diversity and high cover reefs with upwards of 40–50% live hard coral cover **(Fig. 14)**. The fringing fore reef site was emergent, with full exposure to wind and wave action. CCA and cyanobacteria were common. Some larger Acropora colonies were observed **(Fig. 14B)** at depths of 25–30 m. There were no obvious signs of bleaching. A large number of damselfish lawns were observed where turf algae mats were accumulating on old dead corals. Large monospecific colonies of *Echinopora* and *Merulina* colonies were observed growing on the sides of walls. Partial mortality was common on many of the coral colonies observed.

A) *B)* *C)*

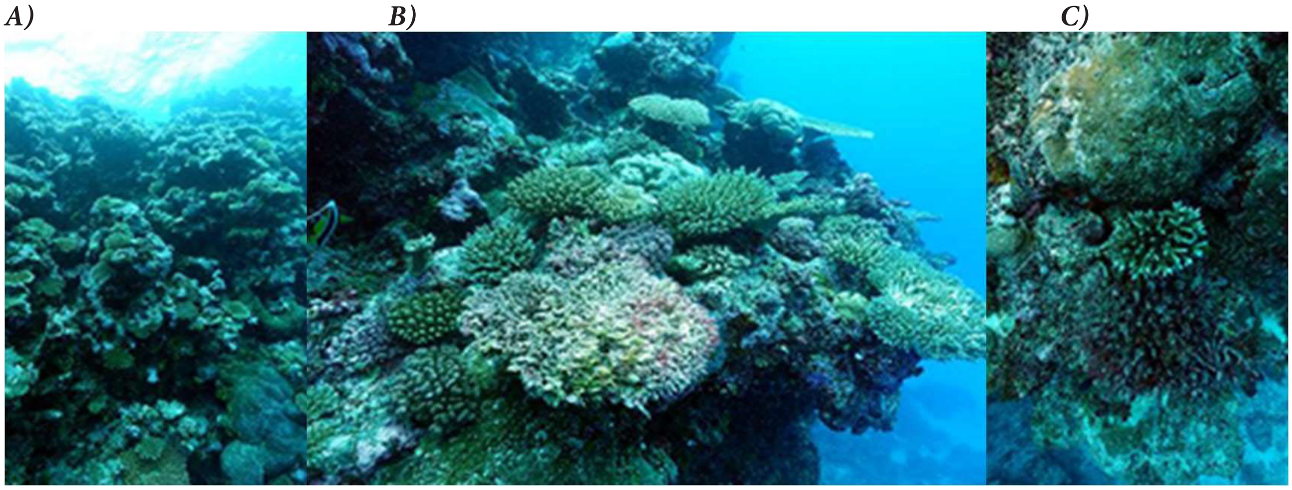

Figure 14: Photographs of Navatu Outer West. A) shows the reef flat with a steep drop to 20 m depth. B) Large Acroporid colonies were found at 25–30 m depth and most showed partial mortality. C) coral coverage and diversity was relatively high on these reefs.

Navatu North Lagoon (NV03). This reef site had a sandy lagoon floor at 10–14 m depth, with various scattered coral bommies and several larger patch reefs reaching almost to the surface **(Fig. 15AB)**. Much of the coral here was dead and had cyanobacteria or macroalgal cover. There was a strong out-flowing current from the centre of the lagoon through the channel. No transects were recorded due to difficult conditions. Large colonies of *Porites* and *Pavona* of at least 2 m in diameter were observed **(Fig. 15C)**. Turf and damselfish lawns were abundant in old dead branching corals. Brown encrusting sponges were common and were overgrowing clean surfaces and recently dead corals.

A) *B)* *C)*

Figure 15: Photographs of Navatu North Lagoon. A) Top of a patch reef with large branching coral reaching almost to the surface. B) Large patch reef surrounded by the sandy lagoon floor at about 14 m depth. C) Large colonies of Porites and Pavona growing on the patch reefs.

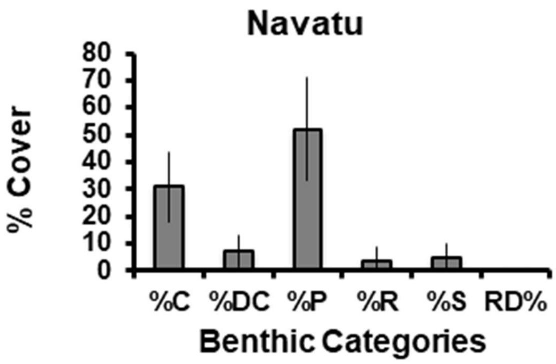

Figure 16: Average benthic cover of the Navatu Outer West and North Channel Pass reefs. Navatu North Lagoon was not included because the currents were too strong to lay out transects. C = live coral, DC = dead coral, P = pavement, R = rubble, S = sand, RD = recently dead coral. All data are presented as percentage cover +/- standard error.

Navatu benthic summary: The Navatu reefs were dominated by pavement (52.2% ± 18.8%), with high living coral cover (31.0% ± 12.8%), and low dead coral (7.3% ± 6.0%), rubble (3.5% ± 5.2%), sand (7.3 % ± 6.0%) and recently dead coral (0.0% ± 0.0%).

IV. Vanua Vatu reefs

<u>**Vanua Vatu North (VT01).**</u> This site had a healthy reef with a wave-washed reef flat (>50% live coral cover) to 4 m, and then a wall to 15 m, including caves and a lot of CCA, a wide plateau from 15–22 m with 30-50% live coral cover, and then a steep slope to 80 m+ **(Fig. 17)**. The fringing fore reef site was submergent with full exposure to wind and wave action. There were little to no signs of predation and disease. Fishing lines were found at the base and the top of the reef. Large *Porites* colonies were common at the base of the slope and coral pinnacles were separated by deep channels. On horizontal and gently sloping fore reef areas there were small boulders, mounds and overlapping sheets of table *Acroporids*, often forming a canopy 1–2 m in height.

A) *B)* *C)*

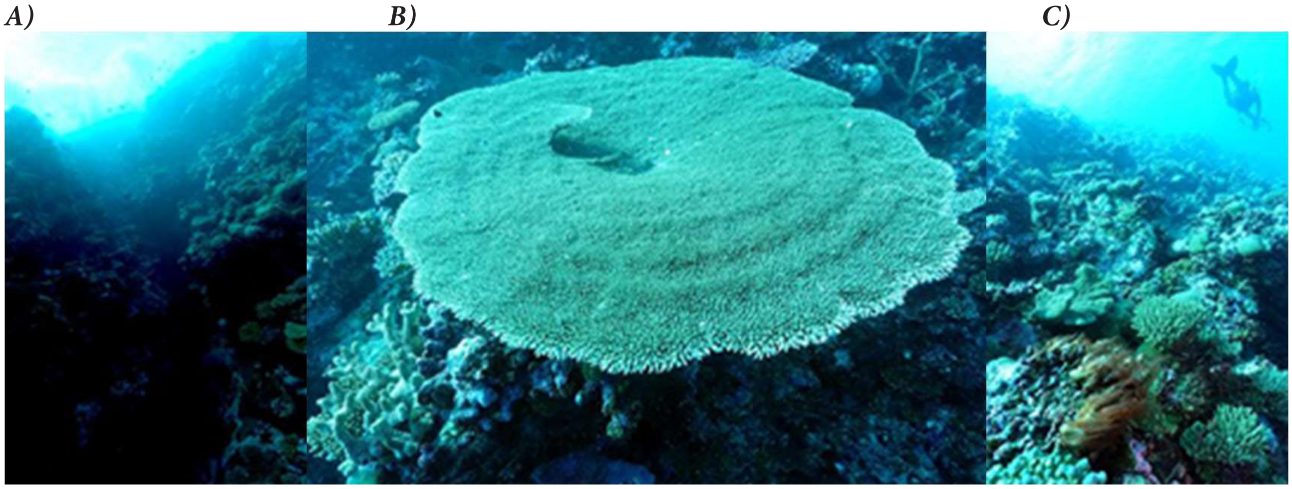

Figure 17: Photographs of Vanua Vatu North. A) Reef profile photo showing the reef flat at around 4 m with a steep wall to 15 m depth. B) Large Acropora table colony growing on the plateau between 15–22 m, C) Reef flat with high coral diversity and coverage at around 4 m depth.

<u>**Vanua Vatu West (VT02).**</u> This site had a wave-washed reef flat with some spur and groove development and 20–25% live hard coral cover. There was a steep slope to 15 m, followed by a plateau from 15–20 m and then a very steep slope into the depths **(Fig. 18)**. The fringing fore reef site on the point of the channel was submergent, with some protection from wind and wave action. About 50% of the deeper reefs were

damaged and lacked extensive coral communities. Many of these deeper reefs were dominated by rubble, overgrown with macroalgae and/or cyanobacteria.

A) *B)* *C)*

Figure 18: Photographs of Vanua Vatu West. A) Reef flat with 20–25% hard coral cover B) Reef profile showing the shallow reef flat with a steep slope down to 15 m. The reef flat and slope had decent coral coverage and diversity. C) Deeper reef site dominated by rubble.

Vanua Vatu North Inner Channel (VT03). This site has rugose spur and groove with numerous caves and tunnels at 1–12 m depth. The shallow reefs had live coral cover of 15–25%, with significant CCA growth in caves. The fringing fore reef site was emergent, with full exposure to wind and wave action. Live coral cover increased at greater depths and was relatively healthy. Fore reef sloped to rubble field, probably due to intense wave action. **(Fig 19)**.

A) *B)* *C)*

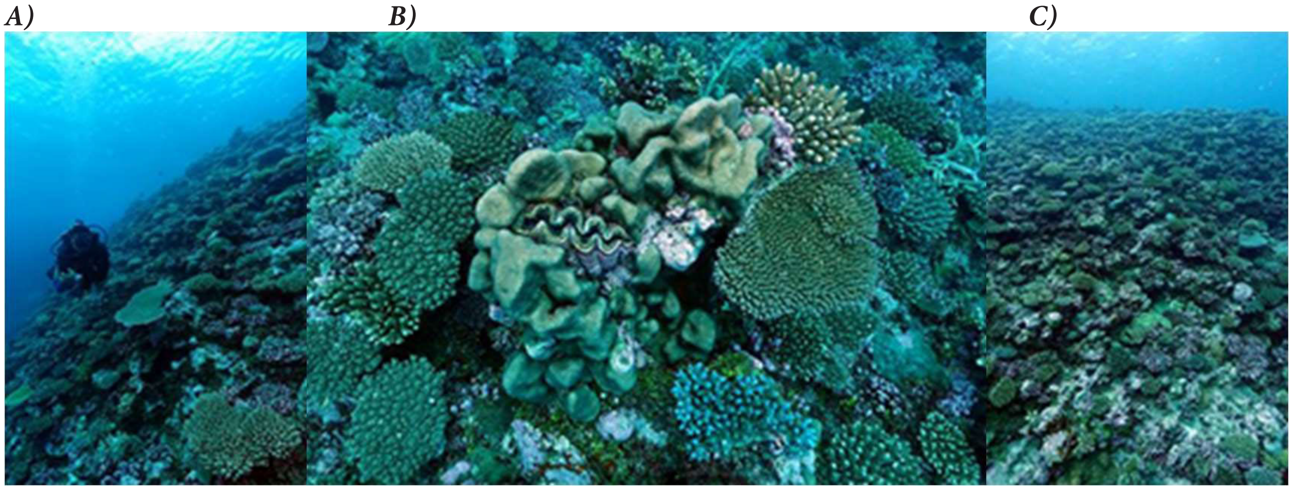

Figure 19: Photographs of Vanua Vatu North Inner Channel. A) wave exposed fore reef site with 15–25% coral coverage. B) Close-up of a deeper reef (15–20 m) with high coral coverage and diversity. C) Reef extending from the reef flat into greater depths.

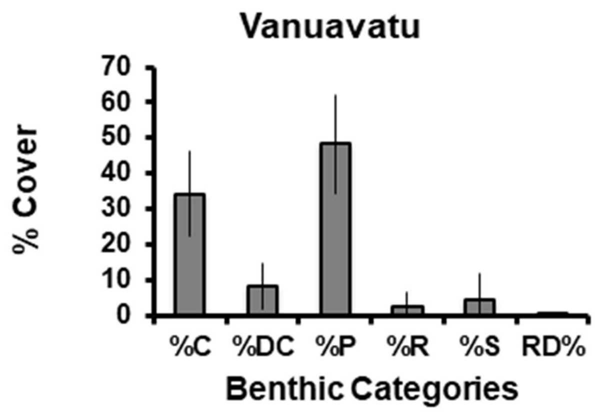

Figure 20: Average benthic cover of the Vanua Vatu North, West and North Inner Channel reef sites. C = live coral, DC = dead coral, P = pavement, R = rubble, S = sand, RD = recently dead coral. All data are presented as percentage cover +/- standard error.

Vanua Vatu benthic summary: The Vanua Vatu reefs were dominated by pavement (48.4% ± 13.9%), with high living coral cover (34.3% ± 11.9%), and low dead coral (8.2% ± 6.5%), rubble (2.5% ± 3.9%), sand (4.5 % ± 7.3%) and recently dead coral (0.0% ± 0.0%)

V. Tavunasici reefs

Tavunasici North (TS01). This site is reef flat with high coral cover (40–60%) with a steep grade to 15–20 m **(Fig. 21)**, where there is a narrow plateau and then a steep grade into the depths. The fringing fore reef on the point of the channel was submergent, with some protection from wind and wave action. Some predation lesions were observed, likely from the *Culcita* cushion star. Topography was rugose with undercuts and small caves, where encrusting corals were prevalent. Corals were observed as deep as 40 m. Macroalgae mats were common at this site.

A) B) C)

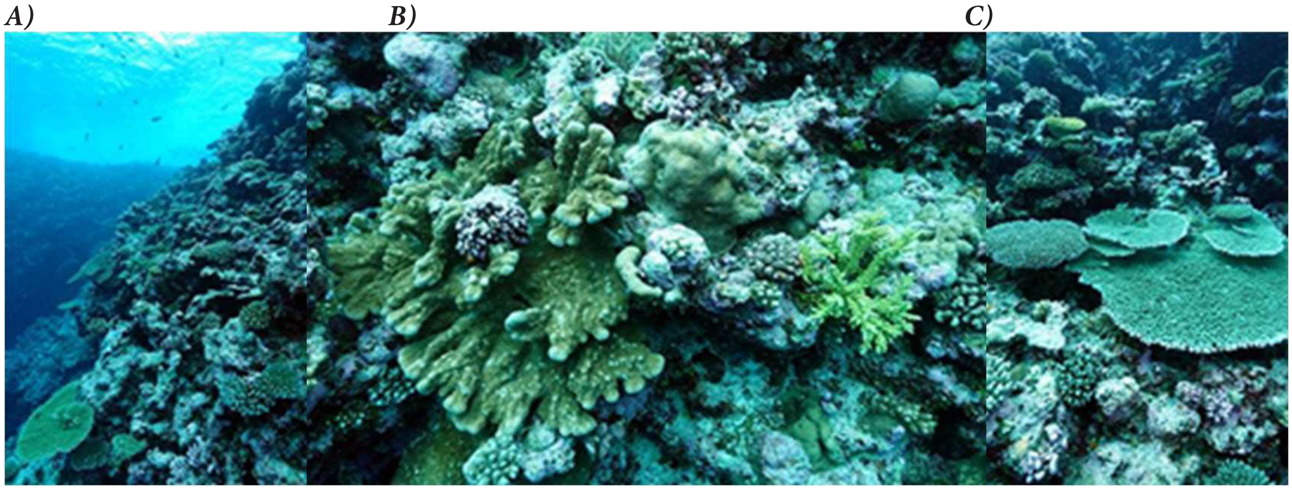

Figure 21: Photographs of Tavunasici North. A) Profile photo showing the steep grade from the reef flat to 15–20m. B) Close-up of the reef flat with high coral coverage and diversity. C) Reef flat with large tabletop Acropora colonies.

TS02 Tavunasici West. This site is outer reef with wave-washed reef top (40–50% live coral cover), then a steep grade to 15 m (40–60% live coral cover), with a narrow sloping plateau at 15–25 m, before becoming almost wall-like with a steep plunge to greater depths **(Fig. 22)**. The fringing fore reef on the point of the channel was submergent, with some protection from wind and wave action. Rubble and turf algae were common around 12–15 m, where there was approximately 35% coral cover but it was patchy. Corallivore predation on small *Pocillopora* and *Acropora* colonies was common.

A) *B)* *C)*

Figure 22: Photographs of Tavunasici West. A) Profile photo showing the steep drop-off beyond 15–25m. B) High wave energy reef top with relatively high coral cover. C) Reef plateau at 15–25m with high coral cover.

Tavunasici Channel (TS03). This site was a channel where the reef flat expels water, with a big sand chute to 25 m and large coral bommies with spur and groove formations on either side, and numerous caves and swim-throughs. Bommies had extensive CCA growth and 15–20% hard coral cover. The fringing fore reef site on the point of the channel was submergent, with some protection from wind and wave action **(Fig. 23)**. The outer reef slope near the reef crest slopes into sand by the entrance to the lagoon. Coral was highly variable between pinnacles. Coral diseases observed included white syndrome and yellow band disease, but overall prevalence was low. There were also areas affected by a crustose coralline algae disease **(Fig. 23C)**.

A) *B)* *C)*

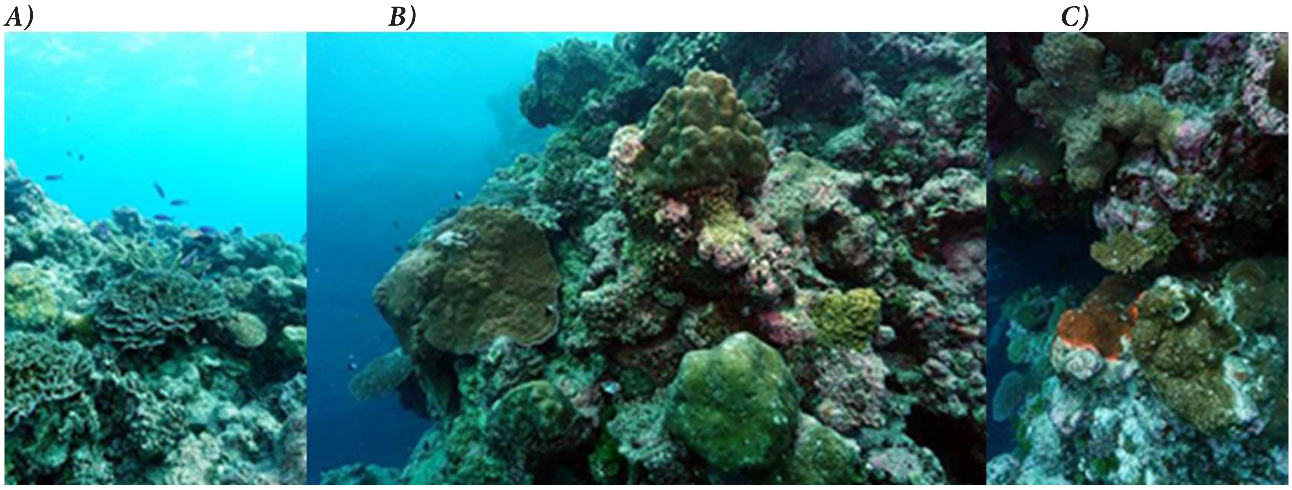

Figure 23: Photographs of Tavunasici Channel. A) Reef flat with large branching and massive coral colonies B) Close-up of the large, massive colonies found on the reef flat. C) Reef plateau at 15–25 m with high coral cover. C) Coralline algae disease.

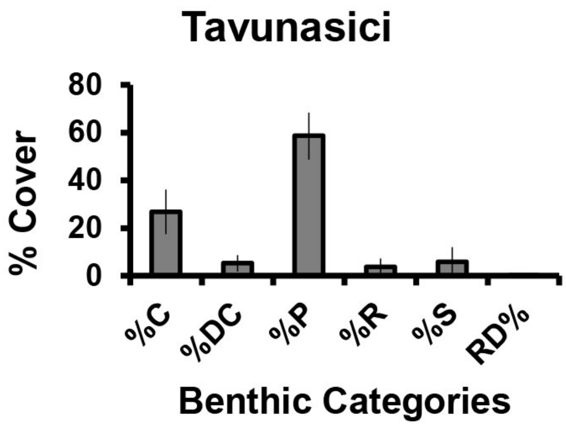

Figure 24: Average benthic cover of the Tavunasici North, West and Channel reef sites. C = live coral, DC = dead coral, P = pavement, R = rubble, S = sand, RD = recently dead coral. All data are presented as percentage cover +/- standard error

Tavunasici benthic summary: The Tavunasici reefs were dominated by pavement (58.6% ± 9.9%), with relatively high living coral cover (26.7% ± 9.4%), and low dead coral (5.2% ± 3.4%), rubble (3.7% ± 3.5%), sand (5.8 % ± 6.2%) and recently dead coral (0.0% ± 0.1%).

VI. Olorua reefs

Olorua North (OL01). Shallow reef on the top of the pinnacles had 15-20% live coral cover, with a short wall to 14m depth where there was approximately 5% live coral and lots of CCA in caves, followed by a plateau with sand, rubble and abundant cyanobacterial mats **(Fig. 25)**. The fringing fore reef site on the point of the channel was submergent with some protection from wind and wave action with low visibility. Turf and cyanobacteria mats were common. The topography of slopes to rubble field were variable with low coral cover. Large *Diploastrea* colonies with partial mortality were common on the sides of the pinnacle slopes **(Fig. 25C)**.

A) *B)* *C)*

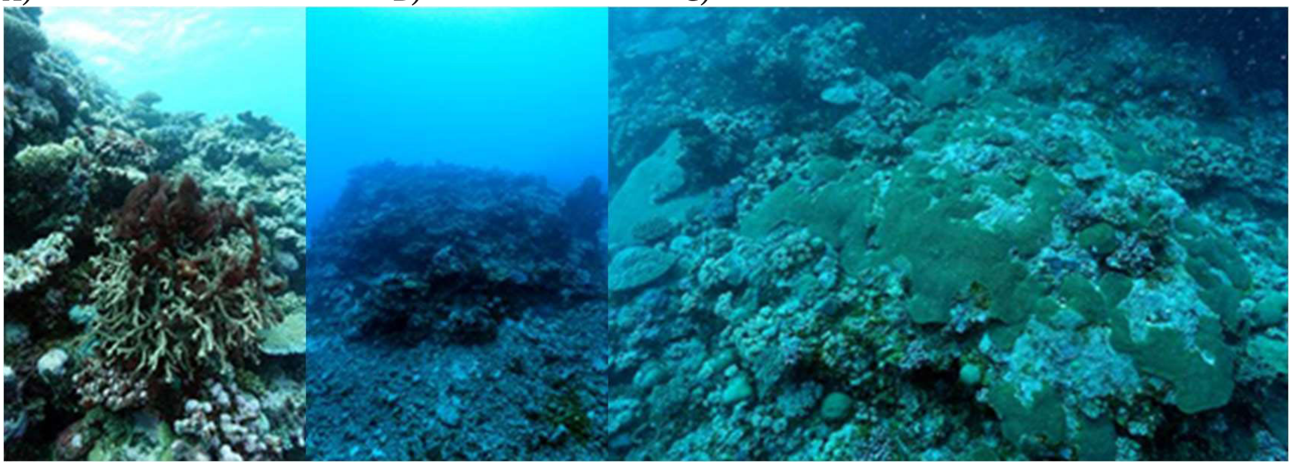

Figure 25: Photographs of Olorua North reef. A) Shallow reefs on the top of pinnacles had15-20% live coral cover with common turf algae and cyanobacterial mats (center). B) Habitat at base of pinnacles around 14m depth with rubble and limited coral cover. C) Large Diploastrea colony with partial mortality.

Olorua South (OL02). This reef site had a gradual slope from 1–25 m, followed by a deep drop-off into the depths **(Fig. 26A)**. There was high coral cover (40–50%) from the shallows to 25 m depth **(Fig. 26B)**. The fringing fore reef site was submergent, with full exposure to wind and wave action. There was a gentle reef slope, with finger-like spurs. Most corals were in good health; it is a very vibrant reef system.

A) *B)*

Figure 26: Photographs of Olorua South reef. A) Shallow reefs with massive plating corals and high coral cover with a gradual slope to 25 m depth. B) High coral cover with great structural complexity from 1–25 m depth.

Olorua West (OL03). This site had a gradual slope from 1–40 m, with numerous spur and groove areas and depressions, and small colonies of *Pocillopora* and *Stylophora* **(Fig. 27A)**. Coral cover was variable, with some parts of the reef having over 50% live coral cover **(Fig. 27B)**, while other parts of the reef had only 20-30% live coral. There was high CCA cover across the reef. The fringing fore reef was submergent, with full exposure to wind and wave action. At 20 m depth, coral cover averaged around 30–35%, but then increased to about 40% cover around 25 m.

A) *B)*

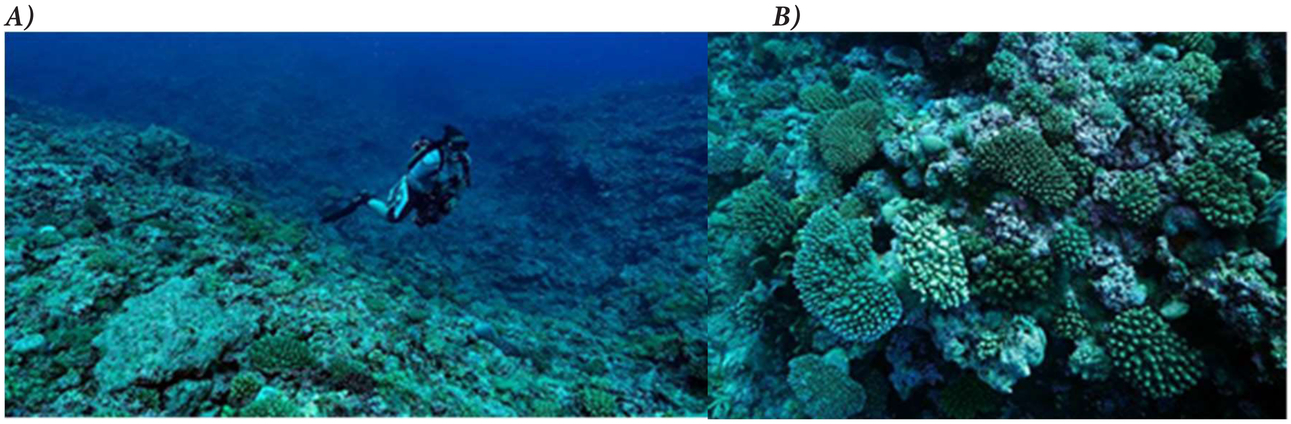

Figure 27: Photographs of Olorua West reef. A) Shallow reefs with a gradual slope to 40 m depth with variable live coral cover. B) There were parts of the reef with over 50% living coral with high coral diversity.

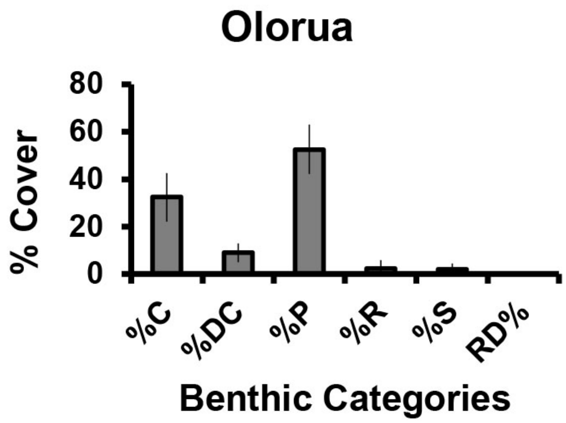

Figure 28: Average benthic cover of the Olorua North, South and West reef sites. C = live coral, DC = dead coral, P = pavement, R = rubble, S = sand, RD = recently dead coral. All data are presented as percentage cover +/- standard error.

Olorua benthic summary: The Olorua reefs were dominated by pavement (52.5% ± 2.4%), with high living coral cover (32.4% ± 10.2%), intermediate dead coral (9.0% ± 4.0%), and low rubble (2.4% ± 3.6%), sand (1.9 % ± 2.7%) and recently dead coral (0.02% ± 0.06%).

VII. Moce Reefs

__**Cakau LekaLeka (MC01):**__ This reef site had a gradual slope with large patch reefs and bommies to 25 m depth followed by a steep grade into deeper depths **(Fig. 29)**. The site had variable coral cover, from 5–30%, with common cyanobacterial mats and turf algae. The fringing fore reef was submergent, with some protection from wind and wave action. Dead corals in standing growth position were common and were mostly covered in either cyanobacteria, turf, or CCA. There were some white, recently dead corals but the cause of mortality was not clear.

A) *B)* *C)*

Figure 29: Photographs of Cakau LekaLeka. A) The shallow part of the reef site had frequent bommies and patch reefs. B) Patch reefs had large branching Acropora colonies and dead coral colonies in standing growth position. C) There were reef areas with over 30% living coral coverage.

__**Cakau Vate (MC02):**__ The shallowest part of the reef was at 0–2 m with a steep drop to 10 m depth. Caves and grooves were common on the shallow reefs, with approximately 10–20% live coral cover, and a sand slope from 10 m to over 60 m depth, with scattered coral bommies and common encrusting Millepora fire coral overgrowth **(Fig. 30)**. The fringing fore reef was submergent, with some protection from wind and wave action.

A) *B)* *C)*

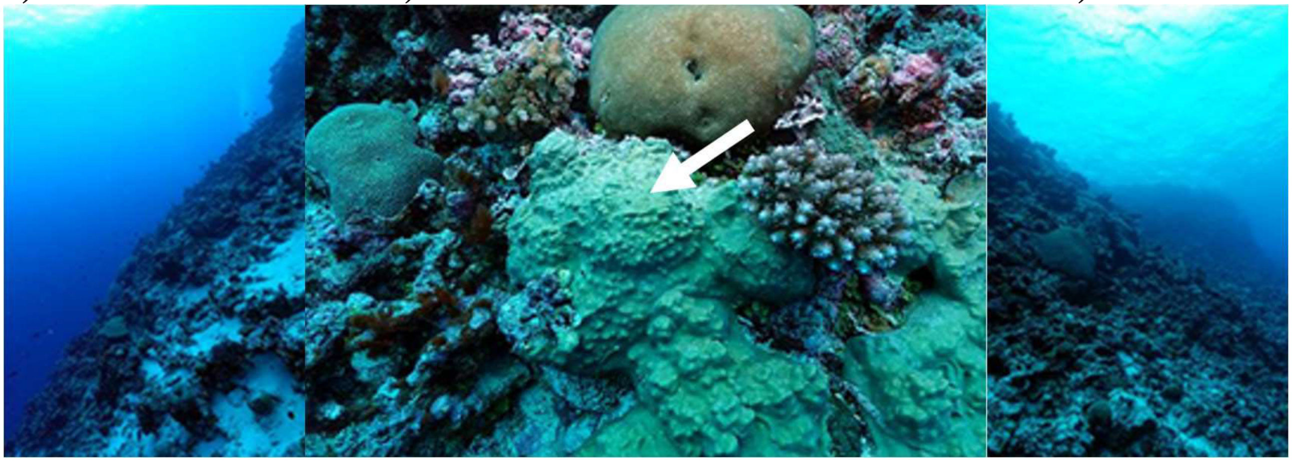

Figure 30: Photographs of Cakau Vate reef. A) This site had a steep drop from 2 m to 10 m depth, with 10–20% living coral cover. B) The shallow reefs at this site had moderate coral cover, often with Millepora fire coral overgrowth, as shown at the white arrow. C) The reef had a steep slope, with large sand patches starting at around 10 m and down to more than 60 m.

Cakau Motu (MC03): This reef site had rugose reef topography with large grooves and isolated spurs. Caves were common and reef cover was generally low, between 5% and 10%, with several sand and rubble patches **(Fig. 31)**. The fringing fore reef was submergent, with some protection from wind and wave action. There was a steep reef slope, starting at 20–25 m. CCA covered most of the substrate, but with little coral recruitment evident. Cyanobacteria were common on old dead *Porites* reef framework.

A) *B)* *C)*

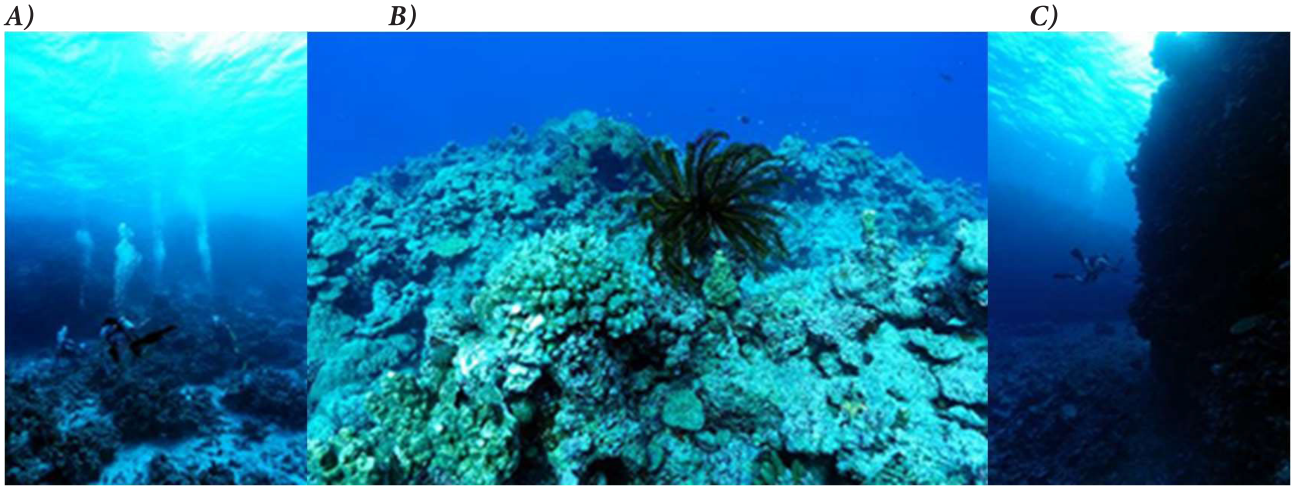

Figure 31: Photographs of Cakau Motu reef. A) Large spur and grooves and a reef slope that started around 20 m depth. B) Low coral cover (5–10%) with common CCA growth on the dead reef framework. C) A steep reef slope started at around 20–25 m and continued to greater depths.

Karoni (MC04): This reef site had a gradual channel pass into Moce lagoon. There was a shallow reef, starting at 1 m depth with a steep drop to 12 m depth. The base of the reef was mostly sand and coral rubble, with scattered coral bommies. There was a gradual sand slope with large patch reefs and 10–20% living coral cover down to about 50 m depth **(Fig. 32)**. The back reef site in the lagoon was protected from wind and wave exposure. At the base of the reef pinnacles there were finger-like structures covered in CCA that were likely old monospecific, columnar frameworks of either *Isopora* or *Pavona* corals. There were coral bommies in the sand flats at around 20 m with predominately small *Acropora* and *Pocillopora* coral colonies. The reef site was dominated by small coral colonies, around 10–20 cm in diameter.

A) *B)*

Figure 32: Photographs of Karoni reef. A). Channel pass on the Karoni reef that passed in to the Moce lagoon. B) A gradual slope from 12 m to over 50 m depths with moderate living coral coverage (~10-20%).

Karoni Lagoon (MC05): Lagoon next to Karoni island – sand with scattered bommies and cyanobacterial mats.

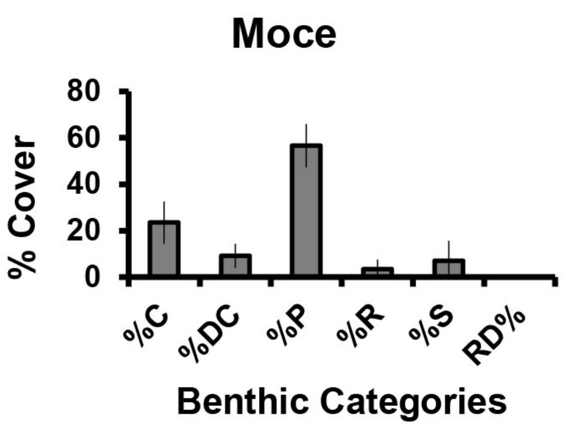

Figure 33: Average benthic cover of the Moce reef sites, including Cakau LekaLeka, Cakau Vate, Cakau Motu, Karoni and Karoni Lagoon. C = live coral, DC = dead coral, P = pavement, R = rubble, S = sand, RD = recently dead coral. All data are presented as percentage cover +/- standard error.

Moce benthic summary: The Moce reefs were dominated by pavement (56.7% ± 9.4%), with relatively high living coral cover (23.6% ± 9.1%), intermediate dead coral (9.2% ± 5.2%), and low rubble (3.6% ± 4.0%), sand (7.0% ± 8.7%) and recently dead coral (0.02% ± 0.1%).

VIII. Matuku Reefs

Matuku West Lagoon (MT01): This reef site is a mangrove-lined lagoon on the west side of Matuku. The site has a gradual reef slope from 1 m to 15 m, with 20-40% live coral cover. Beyond 15 m depth there was mostly silty mud with scattered coral colonies on a gradual slope to 28 m. The back reef site within the lagoon was protected from wind and wave exposure. The fore reef areas were interconnected with lagoonal habitats by a deep channel. Lagoonal areas had extensive seagrass beds and often diverse mangrove communities. Large plating corals were common, but were covered in fine silt and sediment. The site had low coral diversity, likely due to the high sedimentation **(Fig. 34)**. Several corallivores were observed, including crown-of-thorns starfish.

A) *B)*

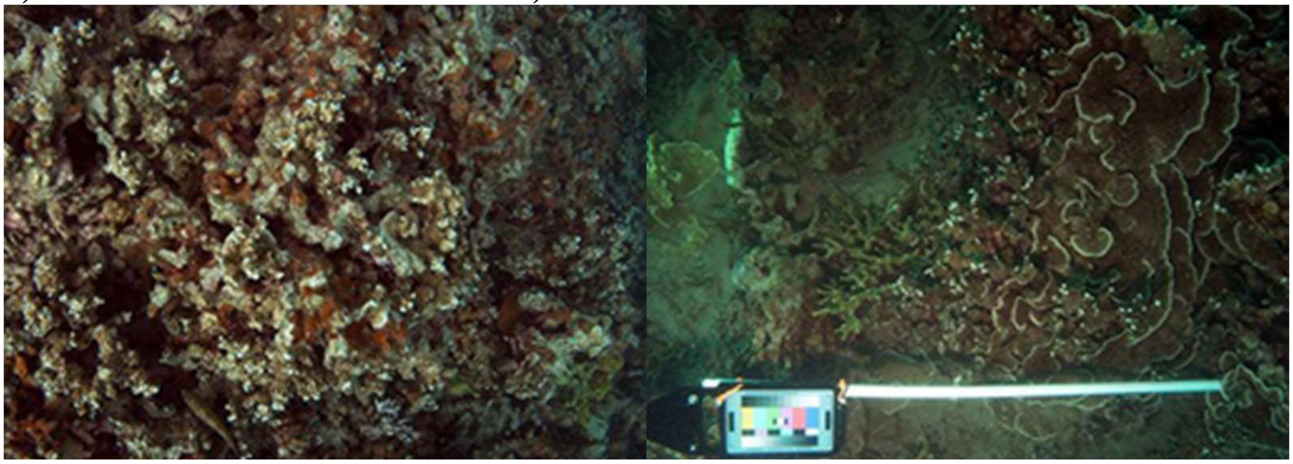

Figure 34: Photographs of Matuku West Lagoon reefs. A) Relatively high coral coverage (20-40%) and low coral diversity. B) Most of the reefs were dominated by a few coral species.

Matuku West Channel (MT02): Reef crest at 2 m depth with 40–50% live coral cover **(Fig. 35A)**. There was then a steep reef slope to 15 m, followed by a sandy rubble slope to 25 m, with a wide coral ridge at 20–30 m depth with 30–40% live coral cover (Fig. 35B). Beyond 25 m depth there was a steep slope to 80 m depth and deeper. The fringing fore reef site was emergent, with full exposure to wind and wave action. The reef site had spur and groove morphology, with steep isolated pinnacles. There were diverse communities of soft corals, especially on the vertical surfaces of pinnacles (especially *Dendronephthya*), as well as branching gorgonians and sea fans. Shallow reef communities and the upper surfaces of pinnacles that were degraded had large mats of leather corals.

A) *B)*

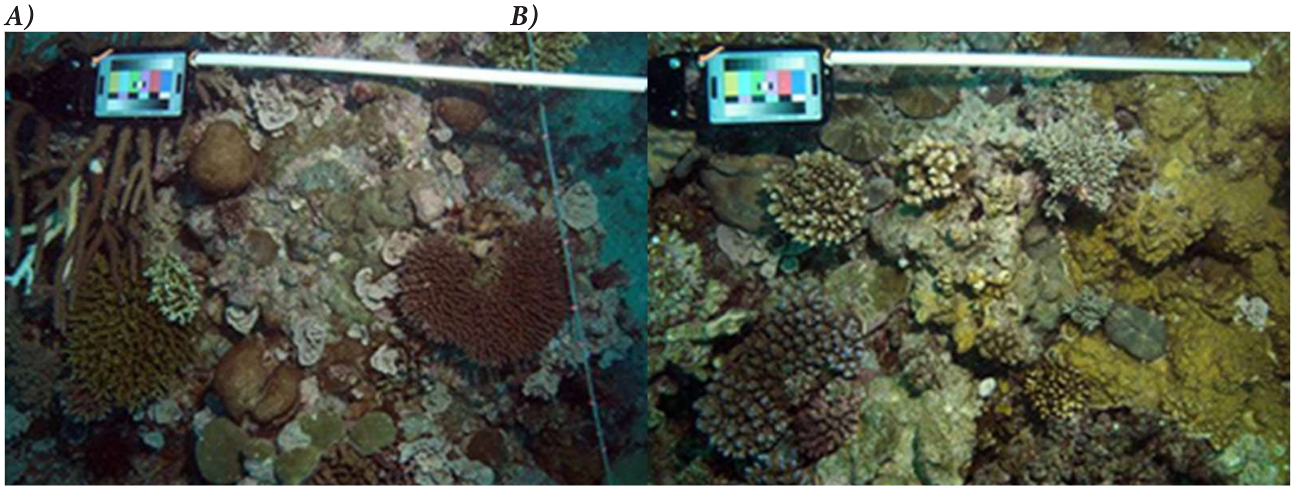

Figure 35: Photographs of Matuko West Channel reefs. A) The reef crest had high coral cover of 40–50%. B) Reefs at 25–30 m depth had relatively high coral cover of 30-40%.

Matuku East Channel (MT03): This site is the channel pass into the eastern Matuko lagoon. The reef started at 1 m depth, with a steep drop-off with a lot of caves to 15 m. This was followed by a steep sand slope to 30 m, with scattered large bommies and pinnacles, all with numerous caves. The site had low live coral cover (10–20%) but a lot of CCA cover **(Fig. 36)**. There was a high diversity of reef building corals, including large *Porites* and *Pavona* colonies. Small submassive corals, such as *Favia* and *Goniastrea*, were common in the shallow areas. Encrusting Millepora fire coral was observed overgrowing dead coral in standing growth form. Leather corals were common on the tops of the pinnacles, leaving little space for coral recruits to settle.

A) *B)*

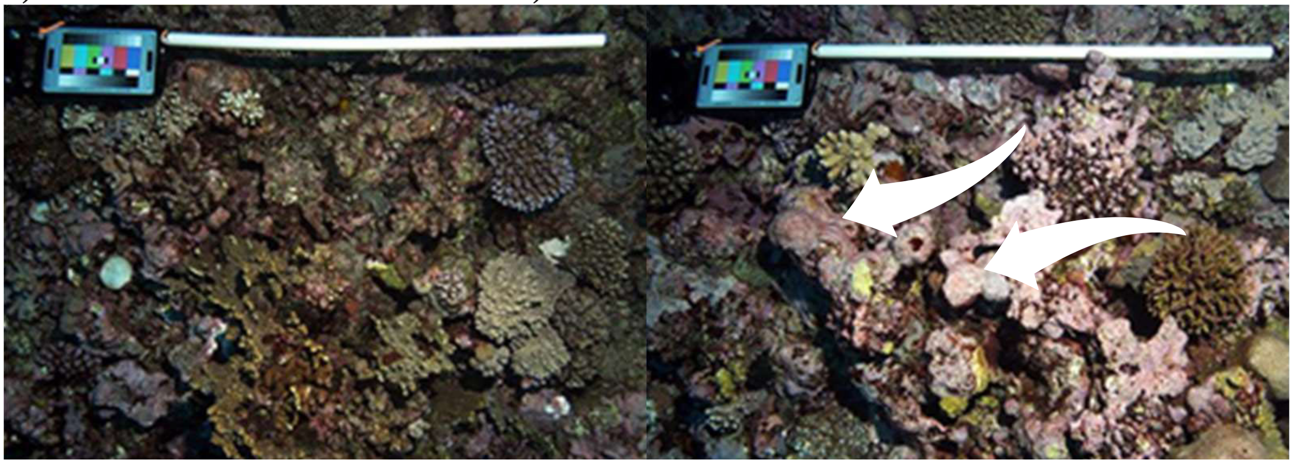

Figure 36: Photographs of Matuko East Channel reefs. A) The high diversity of corals, including submassive Favia and Gonisastrea colonies. B) High cover of CCA shown with a white arrow.

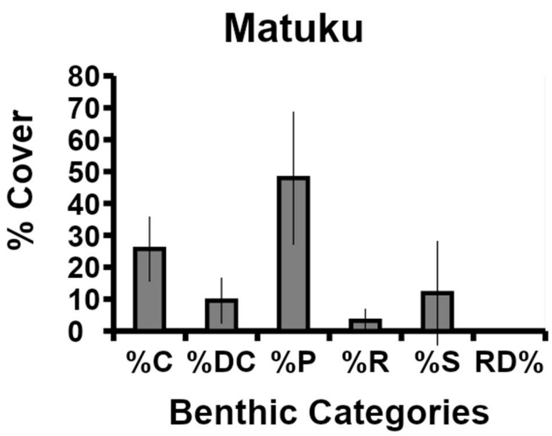

Figure 37: Average benthic cover of the Matuku reef sites, including Matuku West Lagoon, Matuku West Channel, and Matuku East Channel. C = live coral, DC = dead coral, P = pavement, R = rubble, S = sand, RD = recently dead coral. All data are presented as percentage cover +/- standard error.

Matuku benthic summary: The Matuku reefs were dominated by pavement (48.0% ± 20.9%), with relatively high living coral cover (25.7% ± 10.2%), intermediate dead coral (9.5% ± 7.3%) and sand (11.9% ± 16.4%), with low rubble (3.2% ± 3.8%), and recently dead coral (0.0% ± 0.0%).

Site comparison and conclusions

Overall, the sites surveyed were dominated by pavement (range 48.0–64.9%), with relatively high living coral cover (range 20.2–34.3%) and low coverage of sand (range 2.7–11.9%), rubble (range 2.3–4.0%) and recently dead coral (range 0.0–0.1%; Table 3). These benthic coverage results suggest that all the Lau reefs surveyed had healthy benthic communities with almost no recently dead coral. This suggests that there was not bleaching-related mortality associated with the 2016 global bleaching event. The highest percentages of living coral were found in Vanuavatu (34.3% ± 11.9%), Olorua (32.4% ± 10.2%) and Navatu (31.0 ± 12.8), while the lowest percentages were found in Moala (20.2% ± 11.1%), Totoya (21.3% ± 11.2%), and Moce (23.5 ± 9.2%; Table 3).

Table 3: Percentage cover of the dominant benthic types at each of the sites (± %SE). C = live coral, DC = dead coral, P = pavement, R = rubble, S = sand, RD = recently dead coral.

Sites	% C	% DC	%P	%R	%S	%RD
Moce	23.5 ± 9.1	9.2 ± 5.2	56.7 ± 9.4	3.6 ± 4.0	7.0 ± 8.7	0.02 ± 0.08
Moala	20.2 ± 11.1	9.6 ± 6.3	55.0 ± 17.2	3.4 ± 3.6	9.7 ±9.8	0.0 ± 0.01
Matuku	25.7 ± 10.2	9.5 ± 7.3	47.9 ± 20.9	3.2 ± 3.8	11.9 ± 16.4	0.0 ± 0.0
Olorua	32.4 ± 10.2	9.0 ± 4.0	52.5 ± 10.4	2.4 ± 3.6	1.9 ± 2.7	0.02 ± 0.06
Tavunasici	26.7 ± 9.4	5.2 ± 3.4	58.6 ± 9.9	3.7 ± 3.5	5.8 ± 6.2	0.0 ± 0.1
Totoya	21.3 ± 11.2	6.4 ± 4.3	64.9 ± 16.0	2.3 ± 3.6	2.9 ± 4.1	0.0 ± 0.0
Vanuavatu	34.3 ± 11.9	8.2 ± 6.5	48.4 ± 13.9	2.5 ± 3.9	4.5 ± 7.3	0.0 ± 0.0
Navatu	31.0 ± 12.8	7.3 ± 6.0	52.2 ± 18.8	3.5 ± 5.2	4.6 ± 5.4	1.0 ± 0.0

The Lau reefs with the highest living coral cover were Vanuavatu, Olorua and Navatu reefs. These reefs all had over 30% average living coral cover and are sites that should be a priority for protection. All of the reefs surveyed had over 20% living coral cover and represent high diversity, high cover reef ecosystems. Globally, reefs like those documented on this expedition are becoming rarer and degrading rapidly due to rapid climate change. Corals of the Lau area seem to be resilient to climate change and are high diversity reefs worthy of special protection.

Chapter 2: Stony reef corals of the Lau Islands

Doug Fenner

Abstract

The reefs of the Lau Islands have a high diversity (species richness) of stony (hard) corals, with a mean of 62 named species per dive site and a total of 281 species, including 228 named species in 59 genera observed during 25 dives in this brief survey. Some or many of the 53 species which do not fit names in current use are likely to be new species. The number of hard coral species found per dive site was similar to that in New Caledonia, the main islands of Fiji, Tonga, and American Samoa. The total number of stony corals found in 25 dives was highest in the Coral Triangle and New Caledonia, then decreased towards the east from New Caledonia to Fiji, Tonga, and American Samoa. This is consistent with the well-known longitudinal diversity gradient in the Pacific. Astoundingly, the Lau Islands have coral named species richness in 25 dives, which is 84% as high as the four areas in the Coral Triangle the author has surveyed using the same methods. Reef sites that were on outer reef slopes had the greatest species richness of corals, followed by sites in lagoons. One site on an island slope had the lowest richness, but had endemic and micro-endemic species found elsewhere in Fiji.

A total of 281 species, including 228 named species, were found that had not been reported from the Lau Islands before, 12 named species were found that had not been reported from Fiji before (with an additional 15 possible, depending on confirmation from skeleton), and 13 species were recorded that represented extensions of their known biogeographic ranges. A total of 31 species were found that have been listed under the International Union for the Conservation of Nature (IUCN) Red List as Vulnerable, and four species were found that have been listed under the US Endangered Species Act (ESA) as Threatened. Conservation recommendations include the establishment of marine protected areas, protecting the largest reef fish species wherever possible, protecting sea turtles, and monitoring the reefs by repeating our benthic and fish transects annually.

Introduction

Stony or hard corals are a critical component of coral reefs worldwide. Coral reefs are the most diverse of the marine ecosystems. Corals contribute to building the calcium structure of coral reefs (along with certain algae) and are critical to holding reefs together. Further, corals are a primary contributor of habitat diversity used by many species associated with coral reefs, notably fish but also cryptic, sessile and commensal organisms. Corals are highly vulnerable to a range of disturbances, many of which are caused by humans, and are undergoing rapid decline in many, but not all, parts of the world. Coral reefs produce many ecosystem services for people, including fisheries that provide critical food security, shoreline protection, and tourism, worth billions of dollars annually around the world.

Many corals can be identified in situ on coral reefs using field identification guides (Veron 2000) and taxonomic revisions (Hoeksema 1989; Wallace 1999). In situ one can see the entire colony, and often many colonies, while identification from collected specimens often must be based on small samples that do not show the colony shape or range of morphological variation. Although field identification is difficult due to morphological variation within species (Veron 1995, 2000; Todd 2008), it is at least possible, compared with groups such as sponges or ascidians that cannot be identified in the field and require extensive collecting and laboratory analysis. The combination of the critical role of corals for coral reefs, the high diversity of coral reefs, and the ability to identify most coral species rapidly in the field makes them a critical component in any rapid assessment of coral reefs.

The study of corals in Fiji began with the United States Exploring Expedition, led by Charles Wilkes from

1838 to 1842. The expedition collected corals from Fiji in July 1840, among many other locations in the Pacific. James Dana later studied the Fijian corals and wrote a 740-page book, Zoophytes, which included the descriptions of many new coral species, most of which came from Fiji (Dana 1846). A total of 47 species of coral in Zoophytes, currently recognized as valid, were described from skeletons collected in Fiji; Fiji is the "type locality" for those species (Lovell and McLardy 2008).

The study of corals in Fiji has resumed in recent times. These studies are summarized in a single report (Lovell and McCardy, 2008). Six summarized studies report a total of 354 species from Fiji, plus voucher specimens in the University of the South Pacific collection and species for which Fiji is the type location. The studies include one by the author (Fenner 2006). When three additional species are added from a second study in Fiji by the author (Fenner 2007), the total number of species reported from Fiji rises to 357. After Tropical Cyclone Winston hit Fiji in 2016, an expedition led by Wildlife Conservation Society (WCS) and Vatuvara Foundation surveyed marine biodiversity at 33 sites in the Northern Lau Group. The 2017 expedition found 47 coral genera and noted damage from Cyclone Winston on more than half of the reef sites surveyed (Miller et al. 2018).

Most of the world's reef coral species have now been evaluated for their level of risk of global extinction (Carpenter et al. 2008) based on criteria developed by the International Union for the Conservation of Nature (IUCN 2012). The status of individual species is now available from the IUCN website, and species with a heightened risk of extinction found in Fiji are reported in this marine RAP survey. Also, 15 coral species in the Pacific have been listed as "threatened" under the US Endangered Species Act (ESA). Species found in Fiji in this study that are listed as "threatened" under the ESA are also reported here.

Methods

Coral species richness (the number of species) and abundance were surveyed at 27 (of 28, the author did not dive at Site 25) sites while scuba diving for 60 minutes per site, using a 'roving diver' search method. D. Fenner was unable to dive at sites 13 through 19, but corals were identified from photos taken by R. Vave at those sites, except for site 14, where photos were lost. Data were not taken at site 25. A direct descent was made in most cases to about 20–25 m depth. The bulk of the dive consisted of a slow ascent along the reef in a zigzag path to the top of the reef or the shallowest depth that could be reached with a scuba tank, or the shallowest depth safe from heavy surge. The roving diver search method detects more of the species present than belt transects because it covers a larger area. It also distinguishes differences in species richness at different sites, as well as belt transects (Holt et al. 2013). The disadvantage is that the abundance of corals is a qualitative estimate, rather than a quantitative count.

Corals were usually identified in situ, but where an identification could not be made rapidly, a photograph was taken. About 1,170 photos of corals were taken by the author. An attempt was made to take at least a few photographs of all species. Coral species and their abundance were recorded on a printed form on an underwater slate. Species abundance was recorded at the end of the dive using the DAFOR scale, where D stands for dominant, A for abundant, F for frequent, O for occasional and R for rare (Mumby et al. 1996). Rare was defined as only one or two colonies seen, and dominant was defined as over half of all corals or coral cover. Other studies of corals that have used this sort of scale include DeVantier et al. (1998, 2006), Fenner (2006, 2007, 2011, 2015a and 2015b), Richards et al. (2008) and Richards and Beger (2013). Abundance categories were next given a numerical value, by assigning R = 1, O = 2, F = 3, A = 4, and D = 5.

Many corals can be identified to species with certainty in the water and a few must be identified alive, since they cannot be identified without living tissues. In addition, there are some that are easier to identify alive than from skeletons. However, there are some species that normally require collection for verification. Samples of corals that could represent new species were collected at most sites. Samples were later bleached in a household bleach solution, then rinsed in freshwater, dried, and mailed (with a CITES permit) to D. Fenner in American Samoa for further study and description of new species. The species collected are listed below (Table 4).

Table 4. List of corals collected with number of samples

	Genus	No. samples		Genus	No. samples
1.	Acropora	68	8.	Millepora cf exesa	1
2.	Acropora cf jacquelineae	1	9.	Montipora	4
3.	Alveopora	1	10.	Oxypora	7
4.	Astreopora	1	11.	Pavona cf diffluens	1
5.	Cycloseris	1	12.	Phymastrea	1
6.	Fungia cf granulosa	1	13.	Porites	9
7.	Goniastrea	1	14.	Porites nigrescens	4

The nomenclature of Veron et al. (2017) was used as it is the most comprehensive, incorporates most of the newer changes derived from genetics, and takes a cautious approach to proposed name changes. Several comprehensive guides assisted identification (Hoeksema 1989; Wallace 1999; Veron 2000; www.coralsoftheworld.com). The nomenclature of Veron et al (2017) has been followed for fungiids, though the illustrations and descriptions in Hoeksema (1989) were the primary source for actual identification. The nomenclatures of these two authors differ primarily at the level of genera and sub-genera, rather than species (see also Gittenberger, et al. 2011). Additional references used in identifying corals were Randall and Cheng (1984), Veron (2002), Glynn et al. (2001), Razak and Hoeksema (2003), Wolstenholme et al. (2003), Fenner (2005) and Benzoni et al. (2007).

Results

Coral species richness: A total of 281 stony coral species, including 228 named species in 59 genera of named species (including 222 named species in 55 genera of zooxanthellate Scleractinina) were found in this survey. Almost all of the named species are illustrated in Veron (2000) and Veron et al. (2017), most Acropora are illustrated in Wallace (1999), and all fungiids are illustrated in Hoeksema (1989). In this data set, the number of coral species found was strongly and significantly positively correlated with the number of sites in the survey ($r = .67$, $p < .01$). It is difficult in this data set to detect the effect of longitude since the amount of effort (number of sites) was not controlled; they are not comparable measures of species richness.

An average of 62 named coral species were found per dive in this Lau Island survey. The number of species found on the average per dive is much more comparable between areas than the total number of species found in a rapid assessment, because the amount of effort in a single dive (60 minutes) is much more equivalent between studies than the total effort (number of dives), which differs greatly between studies. Figure 38 shows the mean number of named coral species found per 60-minute roving search dive in similar rapid assessments by the same author in the western and South Pacific. The sites are shown in order, going from west to east and left to right. There appears to be a trend of decreasing species richness towards the east, but there is considerable variability in the data.

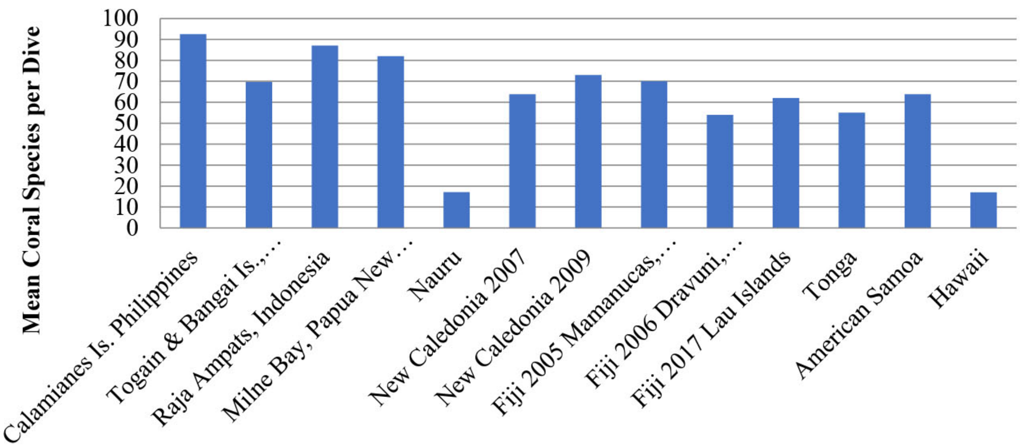

Figure 38. The mean number of named coral species per dive at 13 locations in the Pacific, surveyed by the author, most of which were with Conservation International and all of which used the same methods

Sources: Calamianes: Veron and Fenner, 2000; Togian and Bangai Is.: Fenner, 2001; Raja Ampats: Fenner, 2002; Milne Bay: Fenner and Turak, 2003; Nauru: Fenner, 2015a; New Caledonia 2007: Fenner, 2011; New Caledonia 2009: Fenner and Muir, 2009; Fiji 2005: Fenner, 2006; Fiji 2006: Fenner, 2007; Fiji 2017: Fenner, present report; Tonga: Fenner, 2015b; Hawaii: Fenner, 2006.

A scatter plot of data points other than the two outliers (Nauru and Hawaii) plotted by longitude, shows a linear decrease in species richness in single dives from the Philippines to American Samoa (Figure 39). The correlation of species richness in single dives with longitude was strong ($r = 0.78$) and significant ($p < .005$). The Lau Islands had species richness that was 75% as high as the average of the four Coral Triangle sites, a surprisingly high richness.

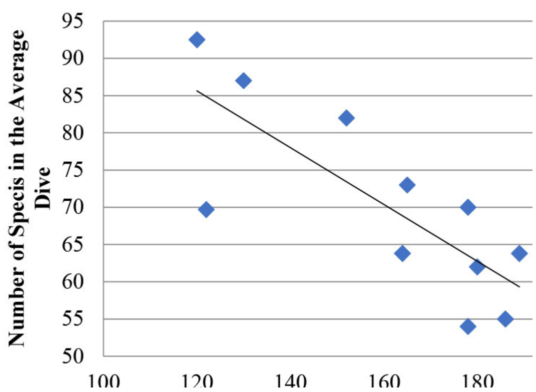

Figure 39. Scattergram of mean coral species richness versus longitude. Data from Figure 38.

The total number of species found in a larger number of dives may be a more sensitive measure of the total biodiversity in an area, since additional effort always increases the total number of species found. With greater effort, the total number of species should be closer to the total that occurs at the area, even though that total is unknown. If the total effort is equated between areas, perhaps that might produce a more sensitive measure than the average number found in a single dive, total found in a survey or the total known from all surveys. Figure 40 shows the total number of coral species found in 25, 60-minute roving search dives, for the same Pacific locations, based on the same data set as in Figure 38. The total number of coral species in 25 dives differs consistently between locations, showing a longitudinal gradient in diversity consistent with the overall pattern for the Pacific (Veron 2000). The total number of species in 25 dives decreases towards the east, similar to the decrease across the entire Pacific. The data also show less variation than the data from single sites. The Lau Islands have species richness that is slightly lower than the main Fiji Islands, but higher than Tonga, consistent with its location. The Lau Islands have coral species richness at 25 dives that is 84% as great as that in the Coral Triangle. This is even higher than the estimate derived from the average of single sites (75%), supporting the view that the Lau Islands have a very high coral species richness.

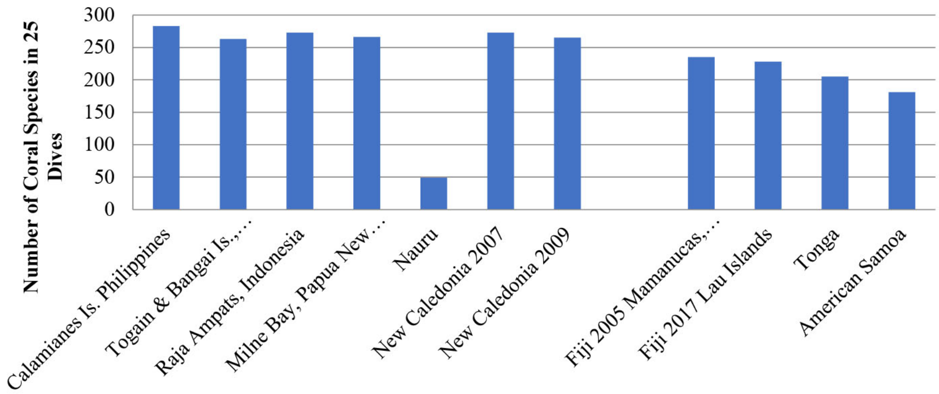

Figure 40. The total number of named coral species recorded by the author in 25 dives at several Pacific locations using the same methods (and most being Conservation International surveys). Nauru had only 20 dives, but would likely not have had many more species with 25 dives.

Sources: as in Fig. 38.

The number of coral species (named and unnamed) at individual sites ranged from 10 to 94 species. The sites with the greatest numbers of coral species were sites 2, 12, 7, 4 and 10, and the sites with the fewest species were sites 9, 15, 26, 17 and 23. The number of species found at each site is shown in Figure 41 and the numbers of species in Table 5. A full list of species found across sites is shown in the Annex (A.1). Figure 42 shows a species rich site.

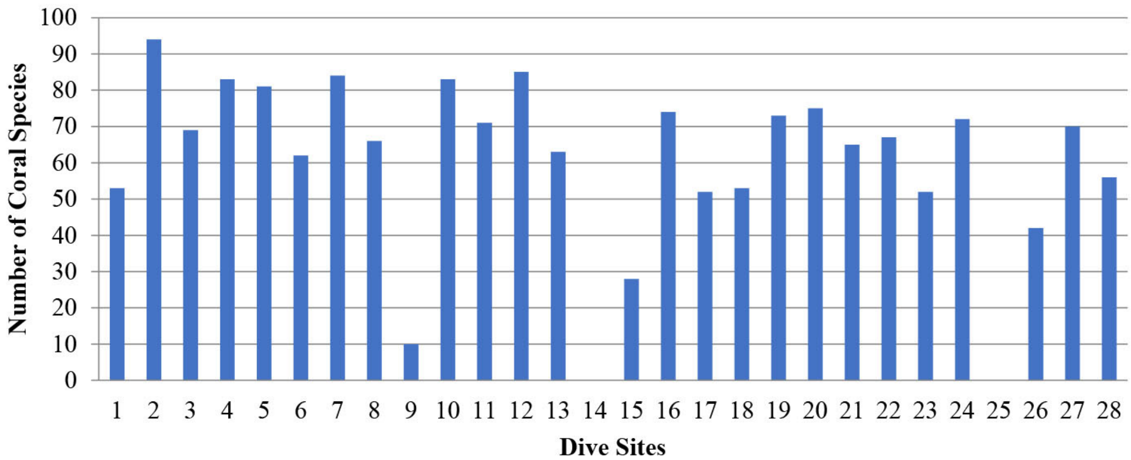

Figure 41. The number of coral species found in each dive site

Table 5. The total number of coral species recorded at each site

Site	Species	Site	Species	Site	Species
1.	53	11.	71	21.	65
2.	94	12.	85	22.	67
3.	69	13.	64	23.	52
4.	83	14.		24.	72
5.	81	15.	28	25.	
6.	62	16.	74	26.	42
7.	84	17.	52	27.	70
8.	66	18.	53	28.	56
9.	10	19.	73		
10.	83	20.	75		

Figure 42. High coral species richness and cover at Site 24 (photo copyright by Douglas Fenner)

Three basic habitats were distinguished: Outer reef slope, lagoon patch reefs, and high island slope. The number of coral species at each site grouped by habitat locations is shown in Figure 43. Outer reef slopes had the highest coral species richness, followed by lagoon patch reefs, followed by the high island slope. There were 16 outer slope sites, eight lagoon sites, and only one island slope site.

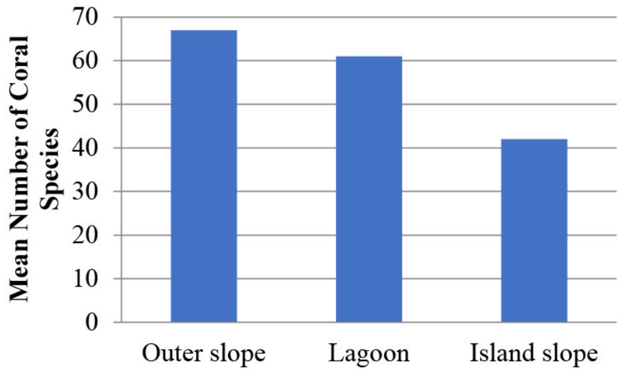

Figure 43. The mean number of coral species in different habitats

General faunal composition: The coral fauna consists mainly of zooxanthellate Scleractinia with 275 species, and only six hard coral species that are not zooxanthellate Scleractinia (Tubipora musica, Millepora dichotoma, Millepora cf. exaesa, Millepora platyphylla, Stylaster sp. and Distichopora violacea). Zooxanthellate Scleractinia are the main reef builders, but Millepora species are also significant reef builders because they are also zooxanthellate and have large skeletons and sometimes are abundant. There were a total of 279 zooxanthellate species and just two species that were not zooxanthellate *(Distichopora violacea and Stylaster sp.)*. This pattern is typical of most reefs. The genera with the most species were Acropora with 74 species, *Montipora* with 21 species, *Pavona* with 12 species, Porites with 14 species, and Fungia with 11 species. In the Indo-Pacific as a whole, Acropora has the most species, followed by *Montipora*, *Porites* and Fungia in that order. The species that was present at the highest percentageage of sites was Leptoria Phrygia, which was present at 92% of the sites; *Pocillopora verrucosa* present at 88% of the sites, *Fungia scutaria, Millepora platyphylla,* and Pavona chiriquensis, which were present at 80% of the sites; and *Coscinaraea columna* and *Goniastrea pectinata* that were present at 76% of the sites. The species that had the highest mean abundance ratings for the sites where they were present were Porites horizontallata (mean rating = 4, based on only one site), Pavona cactus (3, 1 site), Porites rus (2.75, 2 sites), Acropora loripes (2.4, 15 sites), Acropora sp. 12 (2.3, 3 sites), Millepora platyphylla (2.2, 16 sites), and Acropora hyacinthus (2.1, 10 sites). The lowest possible mean abundance score for sites where a species is present is 1.0, with 1 = rare, 2 = uncommon, and 3 = common.

Species of particular interest: Twelve species represent new records from Fiji (see Appendix Table A.1); they had not been reported previously from Fiji. The 12 species that are new records are *Acropora navini, Acropora rosaria, Euphyllia paradivisa, Favia truncatus, Leptoseris foliosa, Parascolymia australis* *(previously referred to as Scolymia australis), Pavona chiriquensis, Porites arnaudi, Porites evermanni, Porites myrmidonensis, Psammocora digitata,* and *Seriatopora guttatus*. An additional 15 species are possible new records, but require confirmation from skeleton samples *(Acanthastrea rotundoflora, Acropora bifurcata, Acropora jacquelineae, Acropora cf. maryae, Acropora valenciennessi, Acropora variolosa, Astreopora ocellata, Pavona cf. diffluens, Pavona giganetea, Platygyra ryunkyuensis, Platygya verweyi, Platygyra yaeyamaensis, Pocillopora brevicronis, Pocillopora danae,* and *Pocillopora molokenis*. Seventeen species records represent range extensions of the known ranges of these species.

The nearest *Euphyllia paradivisa* is presently known to Fiji and American Samoa is Papua New Guinea (Veron et al. 2017). The author first found this species in American Samoa, initially as a single colony. The one colony found in this rapid survey (shown in Figure 44) has the same copper color and contracted tentacles as the initial colony in American Samoa. Several additional colonies with extended green tentacles have subsequently been found in American Samoa by Anthony Montgomery. It is surprising to find a species so far from its known range, with nothing in between, but the colony here helps to fill the gap between American Samoa and Papua New Guinea. It appears we may still have quite a bit to learn about the ranges and occupancy of some coral species.

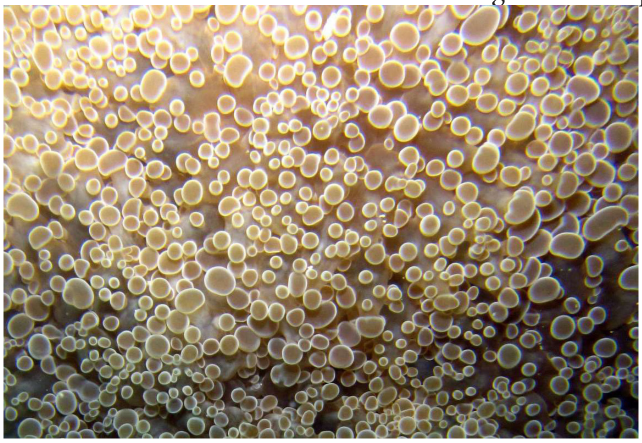

Figure 44. The tentacles of the colony of Euphyllia paradivisa found in the Lau Islands. The identification is partly based on the dividing tentacles. Euphyllia is one of the very few corals where the soft tissue is needed for species identification. Photo copyright Douglas Fenner.

Psammocora digitata is a name that was long applied to a columnar species. A re-examination of type specimens (Benzoni et al. 2007) showed that the columnar species is actually named *Psammocora haimeana* (and the species that name was applied to is a synonym of *Psammocora profundacella*). The coral P. *digitata* actually refers to is usually a massive species that can grow quite large; colonies in American Samoa reach two metres tall and one metre diameter. On rare occasions it can grow in a more columnar shape, which apparently was what it was named after.

The species referred to as '*Pavona* cf. *diffluens*' shown in Figure 45 appears very similar to *P. diffluens* from the Red Sea and western Indian Ocean, illustrated in Veron (2000) and Veron et al. (2017), but Veron (2014) states that it is likely to be another, similar species.

Figure 45. A photo of the colony of Pavona cf. diffluens found in the Lau Islands. Photo copyright Douglas Fenner.

Several coral species have been designated as having an elevated risk of extinction according to the IUCN and/ or the US Endangered Species Act. Carpenter et al. (2008) reviewed all of the world's coral species, using the criteria of the IUCN Red List of endangered species, and came to the conclusion that a third of the world's reef coral species have an elevated risk of extinction. Table lists species found in this study that have an elevated risk of extinction under the IUCN Red List criteria, and the category of risk that was assigned to it by Carpenter et al. (2008) and adopted by IUCN. Table 6 also lists the species listed under the US Endangered Species Act, all four of which were listed as threatened. A total of 31 species were found in this study that were listed under the IUCN Red List as Vulnerable. Four species were found in this study that were listed under the U.S. Endangered Species Act as Threatened.

Table 6. IUCN Red List category assigned by Carpenter et al (2008), and final listings under the US Endangered Species Act for species reported in this study

	Species	IUCN Red List category	US Endangered Species Act
1.	Pocillopora danae	Vulnerable	
2.	Montipora caliculata	Vulnerable	
3.	Isopora crateriformis	Vulnerable	Threatened
4.	Isopora cuneata	Vulnerable	
5.	Acropora aculeus	Vulnerable	
6.	Acropora anthocercis	Vulnerable	
7.	Acropora carolineana	Vulnerable	
8.	Acropora echinata	Vulnerable	
9.	Acropora globiceps	Vulnerable	Threatened
10.	Acropora paniculata	Vulnerable	
11.	Acopora polystoma	Vulnerable	
12.	Acropora retusa	Vulnerable	Threatened
13.	Acropora speciosa	Vulnerable	
14.	Acropora verweyi	Vulnerable	
15.	Astreopora cucullata	Vulnerable	
16.	Euphyllia cristata	Vulnerable	
17.	Euphyllia paradivisa	Vulnerable	
18.	Galaxea astreata	Vulnerable	
19.	Pavona cactus	Vulnerable	
20.	Pavona cf. diffluens	Vulnerable	Threatened
21.	Pavona venosa	Vulnerable	
22.	Leptoseris incrustans	Vulnerable	
23.	Acanthastrea brevis	Vulnerable	
24.	Acanthastrea hemprichii	Vulnerable	
25.	Acanthastrea ishigakiensis	Vulnerable	
26.	Symphyllia hassi	Vulnerable	
27.	Porites horizontallata	Vulnerable	
28.	Porites nigrescens	Vulnerable	
29.	Turbinaria peltata	Vulnerable	
30.	Turbinaria reniformis	Vulnerable	
31.	Turbinaria stellata	Vulnerable	

Several species of coral appear to be new species. The species listed in the Annex as *Acropora* sp. 12 fenneri-like appears to be a new species. The author has also seen, photographed, and sampled it in Tonga, and referred to it as *"Acropora pharaoensis"* in Fenner (2007). The species listed as Acropora sp. 10 latistella-like appears to be a new species the author originally found in American Samoa. *Acropora* sp. 9 appears to be a new species the author first found in Tonga. Astreopora sp. 1 also appears to be a new species the author has found in American Samoa. A distinctive species of *Porites* listed in the Annex as *Porites* sp. 1 also appears to be a new species and is shown in Figure 46. There are also several other species in the genus Acropora which may be new species, one of which is illustrated in Figure 47. Skeleton samples of several of these species were collected, and will need to be studied in detail to determine what they are and name any new species.

Figure 46. A photo of Porites sp. 1, a distinctive lumpy species found in the Lau Islands and listed in Appendix 1 that appears to be a new species. Photo copyright Douglas Fenner.

Figure 47. A photo of Acropora sp. 5, a possible new species found in the Lau Islands. Photo copyright Douglas Fenner.

Discussion

The coral reefs in the Lau Islands host a diverse community of hard corals, about 3/4 of the species in the richest area of coral diversity in the world, the Coral Triangle. This coral species richness is consistent with the Lau Islands' location and the fact that coral richness shows a longitudinal gradient in the Pacific, which is supported by the author's data showing the total number of coral species found in 25 dives in 13 areas of the Pacific. Thus, the species richness of corals appears to be controlled primarily by the distance from the center of diversity, located in the 'Coral Triangle' area of the Philippines, eastern Indonesia, northern Papua New Guinea and the Solomon Islands (Veron 2000; Veron et al. 2009, 2011).

Through this survey, a total of 219 species were found that had not been reported before from the Lau Islands, eight species were found that had not been reported before from Fiji, and 13 species were recorded that represented extensions of their known biogeographic ranges. This MRAP provides significant new information about less or understudied reefs in the Lau Islands. Further study of Fiji reefs is likely to reveal additional species, particularly new species.

The reefs of the Lau Islands have several quite different habitats, such as outer reef slopes, patch reefs in lagoons, and island slopes. The differences between the habitats at individual reef sites contribute to the area richness of coral species, since individual coral species are often more common in specific habitats or even completely restricted to specific habitats. Surveying more habitats increases the number of coral species found. Island slopes were not surveyed adequately in this study, with only one

site surveyed. That site had several coral species not found elsewhere in this study, even though it had lower total species richness than the other types of sites. In addition, reef flats were not surveyed in this study, and additional surveys in shallow habitats like reef flats will very likely add to the total number of species found.

The reefs of the Lau Islands have significant conservation value. There were new records of coral species in Fiji and also range extensions of coral species to Lau reported by Wallace (1999) and Veron (1995). These include corals appeared on lists of threatened species. New records and range extensions are numbered consecutively in the report. All this supports the conservation value of the living corals in the Lau Islands and Fiji as a whole. The information in this report details the number of coral species on individual sites, the coral replenishment and rarity indices for each site, and the threatened species, provides information to assist in the selection of sites for protection as marine protected areas.

The reefs appeared to be in relatively good condition, with limited numbers of dead corals, and limited visible of coral bleaching and coral disease, as well as invertebrate predators (despite a few crown-of-thorn starfish and *Drupella* snails). There was also limited storm damage, limited macroalgae abundance, and limited visible terrestrial sediments. Cyanobacteria were common at some sites. However, large fish and predatory fish were not common, suggesting that fishing pressure is significant. The healthy coral communities provide a strong basis for dive tourism, which would be strengthened by increased populations of large fish, which usually appeal to divers.

Coral restoration in Dravuwalu

Chapter 3: Coral reef fish of the Lau Islands

Semisi Meo, Gerry Allen, and Mark Erdmann

Abstract

A list was compiled of the species observed in 26 of 28 sites in the Lau Archipelago during May 2017. The survey involved approximately 51 hours of diving to a maximum depth of 65 m. The survey yielded a total of 531 species including 288 species not previously recorded from the Lau Group, of which 39 represent new records for Fiji. The present survey also affords an opportunity to comprehensively summarize the reef fish fauna of the Greater Fijian Region, bringing the overall total to 1090 species. The new total is comprised of several elements, including major museum collections, published records, and previous observation by G. Allen.

A formula for predicting the total reef fish fauna based on the number of species in six key indicator families (Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae) indicates that at least 868 species can be expected to occur in the Lau Archipelago. Gobies (Gobiidae), wrasses (Labridae), and damselfish (Pomacentridae) are the dominant family groups in the Lau Archipelago in both number of species (99, 77, and 58 respectively) and number of individuals. Species numbers at visually sampled sites during the survey ranged from 50 to 207, with an average of 159.
One of the most important aspects of the Fijian fauna is its high level of endemism, with 27 species known only in Fiji and an additional 14 species shared with Tonga. At least six new species were collected or observed during the survey, belonging to the following genera: *Symphysanodon (Symphysanodontidae), Luzonichthys (Serranidae), Pomacentrus (Pomacentridae), Ennapterygius (Trypterygiidae), Grallenia (Gobiidae), and Vanderhorstia (Gobiidae)*. Low numbers of sharks, large groupers *(Epinephelus)*, Napoleon wrasse *(Cheilinus undulatus)*, and bumphead parrotfish (Bolbometomon muricatum) were observed during the survey, an indication of over-fishing.

Objective

The objective of the coral reef fish study was to provide a comprehensive inventory of reef fishes inhabiting the Lau Archipelago, as well as an up-to-date review of the entire Fijian reef-fish community. This segment of the fauna includes fish living on or near coral reefs down to approximately 65 m depth. It therefore excludes deep water fish and offshore pelagic species such as flying fish, tunas (except a few reef-frequenting species), and billfish.

Introduction

Fijian ichthyological exploration is divisible into two major eras. The first includes historical collections procured from 1820 to 1936, mostly by European and American expeditions. The second, or modern, era includes post World-War II collections, extending to the present day. The early collections were well-summarized by Australian ichthyologist Gilbert Whitley (1927), as well as American scientist Henry W. Fowler, who published a book, *Fishes of Fiji* (1959). Although Fowler's book was published in 1959, the majority of the manuscript was completed 19 years earlier in 1940, then delayed due to World War II. Like other faunal works published at the time, *Fishes of Fiji* is of limited value due to its non-comprehensive content littered with mis- identifications and recognition of invalid junior synonyms.

The first fish specimens from Fiji were procured by French expeditions between about 1820 and 1837 aboard several ships. Most of the species from these expeditions, many of which were collected or described by the famous naturalists Quoy and Gaimard, were covered in the monumental 22-volume series *Histoire Naturelle des Poissons* by Georges

Cuvier and Achille Valenciennes (1828–1849). Additional collections, totaling 55 lots deposited at the Smithsonian Institution (USNM), were obtained by the U.S. Exploring Expedition, which visited Fiji in July 1840. Numerous fish were also reported from Fiji by Albert Gunther, Curator of Fishes at the British Museum, in his 1880 publication on fish of the British Challenger Expedition that visited Fiji in 1874.

The modern era is highlighted by large collections, mainly procured with the ichthyocide rotenone, by various American and Canadian expeditions. Especially prominent are the collections at the United States National Museum, Washington, D.C, the California Academy of Science, San Francisco (CAS) and the Royal Ontario Museum, Toronto (ROM). The largest holdings of Fiji fish specimens are at CAS, the majority of which were collected by David Greenfield and associates on several trips between 1999-2003. The ROM collection was mainly obtained in 1983 by Alan Emery and Richard Winterbottom. Victor Springer of USNM did extensive collecting in Fiji in 1982, and also collected in Rotuma in 1986. Judging from the huge size and comprehensive nature of the CAS, ROM and USNM collections, it is easy to understand that Fiji is the most thoroughly investigated insular region for reef fishes in the vast western and central Pacific.

Pacific Islanders rely on fish for their way of life. In Fiji, fishing is a vital source of food and income for many households. Fiji's main tourist attraction is also its natural environment and spectacular waters, home to over 1,000 species of reef fish fauna. The main driver of threats to Fiji's fish population is economic development, with threats of over-fishing, pollution from agriculture and industrial waste, urbanization and species introduction (Convention on Biological Diversity (CBD) "Fiji").

Methods

The fish survey involved approximately 51 hours (two people) of scuba diving to a maximum depth of 65 m. A list of fish was compiled for 26 of 28 sites (Appendix Table A.1). The basic method consisted of underwater observations, usually made during a 60–80 minute dive at each site. The name of each observed species was recorded on an Excel spreadsheet, using a master list of expected species from the region as a guide. The underwater technique usually involved rapid descent to 25–50 m, then a slow, meandering ascent back to the shallows. Most of the time was spent in the 5–12 m depth zone, which consistently harbors the largest number of species. Each dive included a representative sample of all major bottom types and habitat situations, such as rocky intertidal, reef flat, steep drop-offs, caves (utilizing a flashlight when necessary), rubble and sand patches. In addition to the routine inventory, the divers were especially on the look-out for unusual/rare species, particularly in deeper sections of the reef (i.e. 30–50 m). Visual observations were supplemented by the occasional collection of cryptic, crevice-dwelling species with clove oil. Spears were also employed for the collection of specimens of interest.

Only the names of fish for which identification was absolutely certain were recorded. However, less than one per cent of those observed could not be identified to species. This high level of recognition is based on our extensive diving experience in the Indo-Pacific and an intimate knowledge of the reef fish of this vast region as a result of extensive laboratory and field studies.

Results

In order to obtain a comprehensive list of Lau Archipelago reef fish resources we have combined the results of the current survey with several other data sources (Table 7): (i) museum specimens deposited at the Academy of Natural Sciences, Philadelphia; the Bishop Museum, Honolulu; the California Academy of Sciences, San Francisco; the Field Museum of Natural History, Chicago; the Royal Ontario Museum, Toronto and the United States National Museum, Washington, D.C.; (ii) miscellaneous records from published literature (e.g. G. Allen's *Damselfishes of the South Seas,* 1975); (iii) underwater observations, many based on underwater photographs by G. Allen during Fiji visits in 2003, 2004, 2005 and 2008; and (iv) underwater images by Australian photographer Josh Jensen and others taken in Fiji waters.

The total reef fish fauna of the Lau Archipelago reported herein consists of 725 species belonging to 72 families and 280 genera (see Annex Table A.1).

In addition, the total for the Greater Fiji Region now stands at 1090 species in 388 genera and 85 families. The totals include 288 new records for the Lau Archipelago, of which 39 represent new records for Fiji (see Annex Table A.1).

Table 7. Faunal elements of Fiji incorporated in this study

Data Source	Lau spp.	Fiji spp.
2017 MRAP survey additions	288	39
Museum surveys (1982–2003)	437	658
G. Allen observations (2003–2008)	---	101
Josh Jensen & other photographers	---	16
Miscellaneous records from literature	---	276
Current total fauna	725	1090

General faunal composition: The most abundant families in terms of number of species are gobies (Gobiidae), wrasses (Labridae), damselfish (Pomacentridae), cardinalfish (Apogonidae), groupers (Serranidae), butterflyfish (Chaetodontidae), surgeonfishes (Acanthuridae), moray eels (Muraenidae), parrotfish (Scaridae), blennies (Blenniidae), and squirrelfish (Holocentridae). These 11 families collectively account for 457 species or about 63 per cent of the total reef fishes currently known from the Lau Archipelago (Table 8).

Table 8. Most abundant families in the Lau Archipelago and Greater Fiji Region

Rank	Family	Species - Lau	Species - Fiji
1	Gobiidae	99	151
2	Labridae	77	86
3	Pomacentridae	58	66
4	Apogonidae	44	64
5	Serranidae	38	62
6	Chaetodontidae	32	34
7	Acanthuridae	31	35
8	Scaridae	21	24
9	Blenniidae	19	52
10	Muraenidae	19	45
11	Holocentridae	19	23

The relative abundance of Lau families is very similar to that found at other Indo-Pacific locations. Gobiidae, Labridae, and Pomacentridae are typically the most speciose families, although the order of these groups varies according to location. The leading position of the Gobiidae is not surprising, as this is the world's largest family of fish with an estimated 2,000 species. Although few moray eels (Muraenidae) were sighted during the survey, the family is well represented in Fijian seas and has been thoroughly sampled, thanks to the use of chemical ichthyocides by museum expeditions. Blennies (Blenniidae) were poorly represented during the Lau survey due to their predilection for very shallow water, both in protected lagoons and on outer reef, and minimal time was spent in these habitats.

The number of species found at each site during the MRAP survey is presented in Table 9. The total for each site ranged from 50 to 207, with an average of 159. The latter figure is not particularly high, but no doubt is due to the homogenous nature of the sampled habitat, which usually consisted of outer-reef slopes.

Table 9. Number of fish species observed at each site during the Lau Archipelago survey

Site	Species	Site	Species	Site	Species	Site	Species
1	125	8	173	15	153	22	173
2	134	9	113	16	146	23	50
3	160	10	150	17	142	26	195
4	131	11	179	18	141	27	207
5	172	12	123	19	170	28	136
6	154	13	179	20	183		
7	188	14	179	21	197		

The richest sites for fish diversity are indicated in Table 10. Matuku Island has the highest faunal diversity, with 298 species recorded for the three sites at this island, which included channels near the outer reef (sites 26 and 28) and sheltered lagoon habitat (site 26).

Table 10. Richest sites for fishes during 2017 Lau survey

Site No.	Location	Total fish spp.
27	Matuku West Channel	207
21	Cakau Motu	197
26	Matuku West Lagoon	195
7	Navatu Outer Reef West	188
20	Cakau Vate	183

Coral Fish Diversity Index (CFDI):): In response to the need for a convenient method of assessing and comparing overall coral reef fish diversity between areas in the Indo-Pacific region, the author devised a rating system (see Allen and Werner, 2002) based on the number of species present belonging to the following six families: Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae. These families are particularly good indicators of overall fish diversity for the reasons below.

- They are taxonomically well documented.
- They are conspicuous diurnal fish that are relatively easy to identify under water.
- They include the “core” reef species, which, more than any other fish, characterize the fauna of a particular locality. Collectively, they usually comprise more than 50 per cent of the observable fish.
- The families, with the exception of Pomacanthidae, are consistently among the 10 most speciose groups of reef fish inhabiting a particular locality in the tropical Indo-west Pacific region.
- Labridae and Pomacentridae in particular are very speciose and utilize a wide range of associated habitats in addition to coral-rich areas.

The method of assessment consists simply of counting the total number of species present in each of the six families. It is applicable at several levels:

- single dive sites
- relatively restricted localities such as the Lau Archipelago
- countries, major island groups, or large regions.

CFDI values can be used to make a reasonably accurate estimate of the total coral reef fish fauna of a particular locality by means of a regression formula. This feature is particularly useful for large regions, such the central tropical Pacific, where reliable totals are lacking. Because the CFDI groups can be comprehensively documented over a short period of time (usually about two weeks for areas such as the Lau Archipelago), the CFDI predictor value can be used to gauge the thoroughness of a particular short-term survey that is either currently in progress or already completed.

The above-mentioned regression formula was obtained from an analysis of 35 Indo-Pacific locations that have been comprehensively studied and for which reliable species lists exist. The data were first divided into two groups: those from relatively restricted localities (surrounding seas encompassing less than 2,000 km2) and those from much larger areas (surrounding seas encompassing more than 50,000 km2). Simple regression analysis revealed a highly significant difference (P = 0.0001) between these two groups. Therefore, the data were separated and subjected to an additional analysis. The Macintosh program Statview was used to perform simple linear regression analyses on each data set in order to determine a predictor formula, using CFDI as the predictor variable (x) for estimating the independent variable (y) or total coral reef fish fauna. The resultant formulae were obtained: (i) total fauna of areas with surrounding seas encompassing more than 50,000 km2 = 4.234 (CFDI) – 114.446 (d.f = 15; R2 = 0.964; P = 0.0001); and (ii) total fauna of areas with surrounding seas encompassing less than 2,000 km2 = 3.39 (CFDI) - 20.595 (d.f = 18; R2 = 0.96; P = 0.0001).

The following CFDI values were obtained for the archipelago, after combining the results of this survey with those of previous museum collections (mainly CAS, ROM and USNM): Chaetodontidae (32), Pomacanthidae (13), Pomacentridae (58), Labridae (77), Scaridae (21), and Acanthuridae (31). The total CFDI (232) was then used to predict the expected species total with the following formula: total expected fauna = 4.234 (232) – 114.446. Therefore, the expected total species for the Lau Archipelago is 868 species. The CFDI method is especially useful when time is limited and there is heavy reliance on visual observations, as was the case for the present survey. This result indicates that at least 145 additional species can be expected with more complete sampling, including the use of chemical ichthyocides. Using the same formula for the Greater Fiji Region, which has a CFDI of 263, the estimated total species is 999. However, the actual number of species thus far recorded for the region (1062) exceeds this total, indicating the very comprehensive nature of the past collecting effort that includes extensive use of chemical ichthyocides for recording cryptic, seldom-seen species.

Table 11 presents a comparison of the Lau Archipelago and Greater Fiji Region with various Indo-west and central Pacific locations that were surveyed in the past by the author or colleagues.

Table 11. Coral fish diversity index (CFDI) values for selected localities in the Indo-west Pacific region. The total number of fish thus far recorded from each region and estimated total, based on the CFDI regression formula (see text for details) are also indicated.

Locality	CFDI	No. reef fishes	Estim. reef fishes
Raja Ampat Islands, Indonesia	374	1471	1469
Bali and Nusa Penida, Indonesia	339	1022	1320
Milne Bay Province, Papua New Guinea	333	1109	1313
Maumere Bay, Flores, Indonesia	333	1111	1108
Halmahera, Indonesia	327	974	1271
Fakfak-Kaimana, W. Papua, Indonesia	322	1007	1249
Timor I. (Indonesia) & East Timor	318	958	1232
Berau, E. Kalimantan, Indonesia	316	875	1051
Togean and Banggai Islands, Indonesia	308	819	1190
Cenderawasih Bay, W. Papua, Indonesia	308	1002	1190
North Sulawesi, Indonesia	307	967	1020
Solomon Islands	301	1019	1160
Calamianes Islands-N. Palawan, Philippines	292	1003	1122
Komodo Islands, Indonesia	280	722	929
Yap State, Micronesia	280	787	929
Verde Passage, Luzon, Philippines	278	750	922
Sabah, Malaysia	275	865	1050
Greater Fiji Region	263	1062	999
Madang, Papua New Guinea	257	787	850
Kimbe Bay, Papua New Guinea	254	687	840
Lau Archipelago, Fiji	232	723	868
Capricorn Group, Great Barrier Reef	232	803	765

Brunei, Darussalam	230	673	759
Chuuk State, Micronesia	230	615	759
Western Thailand (Andaman Sea)	226	775	843
Ashmore/Cartier Reefs, Timor Sea	225	669	742
Kashiwa-Jima Island, Japan	224	768	738
Anambas Islands, Indonesia	216	667	801
Samoa Islands	211	852	694
Chesterfield Islands, Coral Sea	210	699	691
Pohnpei and nearby atolls, Micronesia	202	470	664
Layang Layang Atoll, Malaysia	202	458	664
Andaman Islands	200	535	732
Bodgaya Islands, Sabah, Malaysia		516	647
Pulau Weh, Sumatra, Indonesia	196	533	644
Izu Islands, Japan	190	464	
Sipadan Island, Sabah, Malaysia	184	492	603
Phoenix Islands, central Pacific	176	514	576
Rowley Shoals, Western Australia	176	505	576
Cocos-Keeling Atoll, Indian Ocean	167	528	545
North-West Cape, Western Australia	164	527	535
Lord Howe Island, Australia	139	395	450
Monte Bello Islands, W. Australia	119	447	382
Bintan Island, Indonesia	97	304	308
Kimberley Coast, Western Australia	89	367	281
Johnston Island, Central Pacific	78	227	243
Midway Atoll	77	250	240
Rapa	77	209	240
Norfolk Island	72	220	223

Zoogeographic affinities of Fijian reef fish: Table 12 presents the major zoogeographic categories for reef fish of Fiji. The largest segment of the fauna consists of species that exhibit broad distributions, ranging from circumglobal species to those mainly distributed in the western and central Pacific. The vast majority of species range widely in the Indo-west and central Pacific region, from the western and central Indian Ocean to the islands of Oceania or, in the case of 19 species, to the mainland or offshore islands of Central and South America. Such distribution patterns are not surprising, given that nearly all coral reef fish have pelagic larval stages of variable duration. Dispersal capabilities and length of larval life of a given species are usually reflected in its geographic distribution. For example, surgeonfish of the genus Acanthurus typically have extensive Indo-Pacific distributions and relatively long pelagic stages that range from about 36 to 69 days.

Table 12. Major Zoogeographic categories for Fijian reef fish

General distribution	No. species	% of fauna
Indo-west and central Pacific	672	61.9
Western and central Pacific	275	25.3
Fijian endemics	27	2.5
Southwestern Pacific	25	2.3
Indo-Pacific to Americas	19	1.7
Circumglobal	16	1.5
Undetermined	15	1.4

Fiji and Tonga	14	1.3
South Pacific	12	1.1
Central Pacific	7	0.6
Fiji-Tonga-Samoa	3	0.3
Fiji and Samoa	1	0.1

A combined total of 37 species is mostly restricted to the South Pacific region, extending from New Guinea and Australia's Great Barrier Reef to French Polynesia. This group is divisible into 25 species that primarily occur in the southwestern portion of this region (for example, frequently from the Coral Sea, Vanuatu, or New Caledonia to Fiji or Samoa) and 15 species that range farther to the east, to the Marquesas or Tuamotu Archipelago. Fiji lies just to the west of the Pacific Plate boundary (which passes between Fiji and Samoa, Springer 1982) and only seven Fijian species are mainly confined to this region that encompasses the islands of central Oceania. Typical examples of this segment of the fauna include *Anarchias leucurus* (Muraenidae), *Pseudocheilinus tetrataenia* (Labridae), *Helcogramma hudsoni* (Tripterygiidae), and *Cirrpectes variolosus* (Blenniidae).

Reef fish diversity is greatest in the Indonesian region, and there is a more or less predictable attenuation of the fauna as one travels away from this area, especially in an eastward direction (Table 13).

Table 13. Comparison of total number of reef fish for various locations in the western and central Pacific Ocean (adapted from Allen, 2002)

Location	Total species
Indonesia	2582
Papua New Guinea	1823
Fiji	1086
Phoenix Islands	514
Society Islands	560
Tuamotu Islands	389
Marquesas Islands	331

Endemism: Fiji has a remarkable number of endemic species, despite the broad dispersal capabilities via the pelagic larval stage of most reef fish. This study indicates that 27 species are presently known only in Fiji (Table 14 and Figure 48). This high number of endemics is perhaps the most outstanding aspect of the Fijian reef fish fauna. Although forming a relatively small percentage of the overall species total, endemic species are extremely important for their role as conservation icons and can be used to help justify the importance of local marine protected areas. For example, the 15 endemic species that occur at Cenderawasih Bay in West Papua Province of Indonesia have been effectively used to promote conservation in the region, including the establishment of the largest marine national park in Indonesia.

Table 14. Endemic reef fish of Fiji

FAMILY	SPECIES
Ophichthidae	Bascanichthys fijiensis
Congridae	Gorgasia thamani
Ophidiidae	Brotula flaviviridis
Bythitidae	Dermatopsis greenfieldi
Bythitidae	Diancistrus fijiensis
Bythitidae	Diancistrus robustus
Plesiopidae	Plesiops polydactylus

Apogonidae	Zoramia febila
Pomacanthidae	Centropyge deborae
Labridae	Cirrhilabrus marjorie
Blenniidae	Ecsenius fijiensis
Blenniidae	Ecsenius pardus
Blenniidae	Meiacanthus ovalauensis
Blenniidae	Petroscirtes pylei
Callionymidae	Synchiropus springeri
Gobiidae	Eviota eyreae
Gobiidae	Eviota karaspila
Gobiidae	Eviota mimica
Gobiidae	Eviota richardi
Gobiidae	Eviota teresae
Gobiidae	Eviota thalmani
Gobiidae	Grallenia new species
Gobiidae	Trimma bathum
Gobiidae	Trimma finistrinum
Gobiidae	Vanderhorstia bella
Ptereleotridae	Parioglossus triquetrus
Siganidae	Siganus uspi

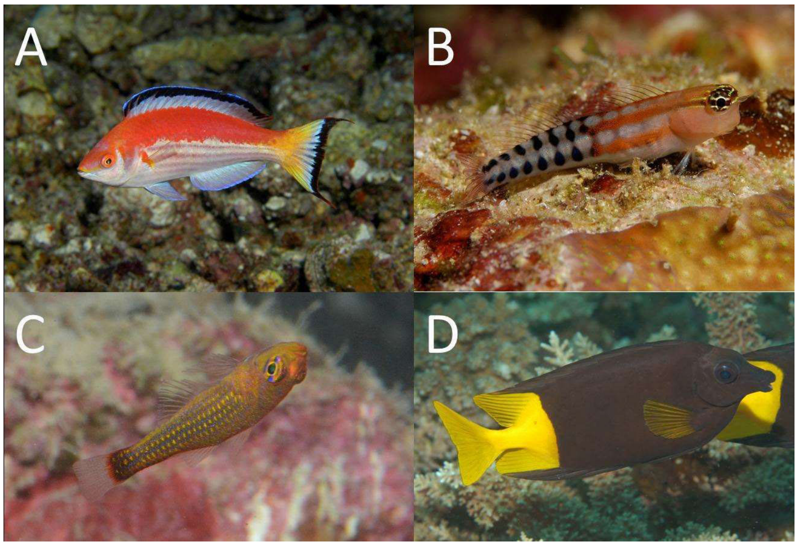

Figure 48. A selection of Fijian endemic reef fish: A. Cirrhilabrus marjorie (Labridae); B. Ecsenius fijiensis (Blenniidae); C. Trimma finistrinum; D. Siganus uspi (Siganidae)

None of the Fijian endemics are confined to the Lau Archipelago and the majority, including the cusk eel (Ophidiidae), viviparous brotulas (Bythitidae), longfin (Plesiopidae), gobies (Gobiidae), and dartfish (Ptereleotridae), are mainly tiny or cryptic inhabitants of caves and ledges. The only endemics belonging to the remaining, more obvious families that were detected during the present Lau survey include blennies (*Ecsenius* and *Meiacanthus*) and rabbitfish (*Siganus*).

Fiji-Tonga endemism: It is highly probable that most of the 27 species listed above also occur in Tonga, but due to their small size and/or cryptic habits they have avoided detection. The present study indicates that 14 species are shared by Fiji and Tonga (Table 15 and Figure 49) and three additional species, including two anemonefishes (*Amphiprion barberi* and *A. pacificus*) and a sandperch (*Parapercis xanthogramma*), are also shared with the Samoan Archipelago. The two anemonefish, in particular, are potentially important conservation icons, due to their high visibility and general public awareness of the symbiotic relationship between anemonefish and their invertebrate host.

Table 15. Fiji-Tonga regional endemics

FAMILY	SPECIES
Bythitidae	Alionematichthys winterbottomi
Pseudochromidae	Pseudochromis melanurus
Apogonidae	Siphamia fraseri
Pomacentridae	Neoglyphidodon carlsoni*
Pomacentridae	Pomacentrus callainus
Pomacentridae	Pomacentrus maafu
Pomacentridae	Pomacentrus microspilus
Pomacentridae	Pomacentrus spilotoceps
Pomacentridae	Pomacentrus cf imitator
Tripterygiidae	Helcogramma ceracina
Blenniidae	Meiacanthus bindoon
Blenniidae	Plagiotremus flavus
Blenniidae	Rhabdoblennius nigropunctatus**
Gobiidae	Trimma anthrenum

*Also known from New Caledonia from single "vagrant".
**Also occurs in Niue.

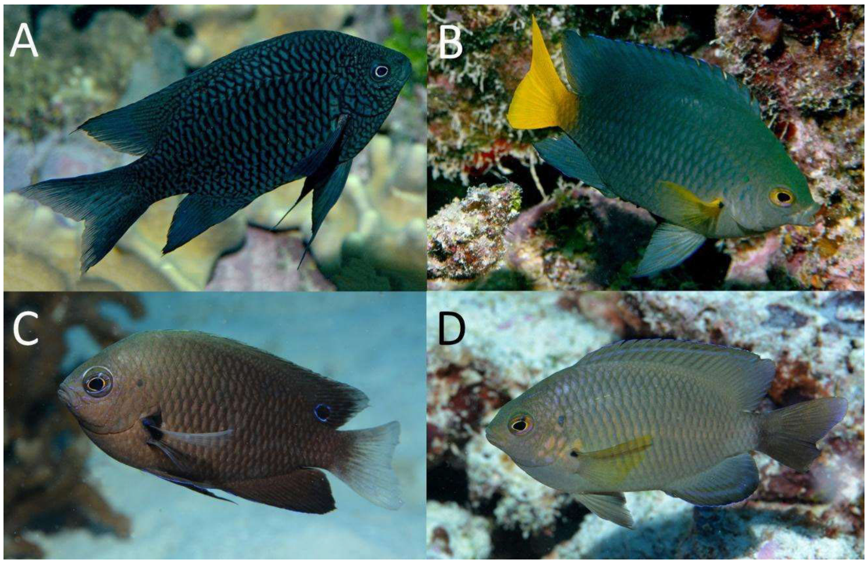

Figure 49. Damelfish (family Pomacentridae) endemic to the Fiji-Tonga region: A. Neoglyphidodon carlsoni; B. Pomacentrus maafu; C. Pomacentrus microspilus; D. Pomacentrus spilotocep.

Fiji colour variation: An interesting, unique aspect of the Fijian reef fish fauna is the presence of unusual localized colour variation in several common, widely distributed species. In at least three cases, involving the damselfish *Pomacentrus maafu* and the blennies *Meiacanthus ovalauensis* and *Plagiotremus flavus*, genetic evidence reveals that the Fijian fish are distinct species, separate from the widely distributed "parent" species *Pomacentrus mollucensis, Meiacanthus atrodorsalis* and *Plagiotremus laudanus*. Further genetic testing will help to resolve the status of other Fijian variants, including *Scolopsis bilineatus, Chrysiptera talboti and Labroides dimidatus*, which are illustrated in Figure 50.

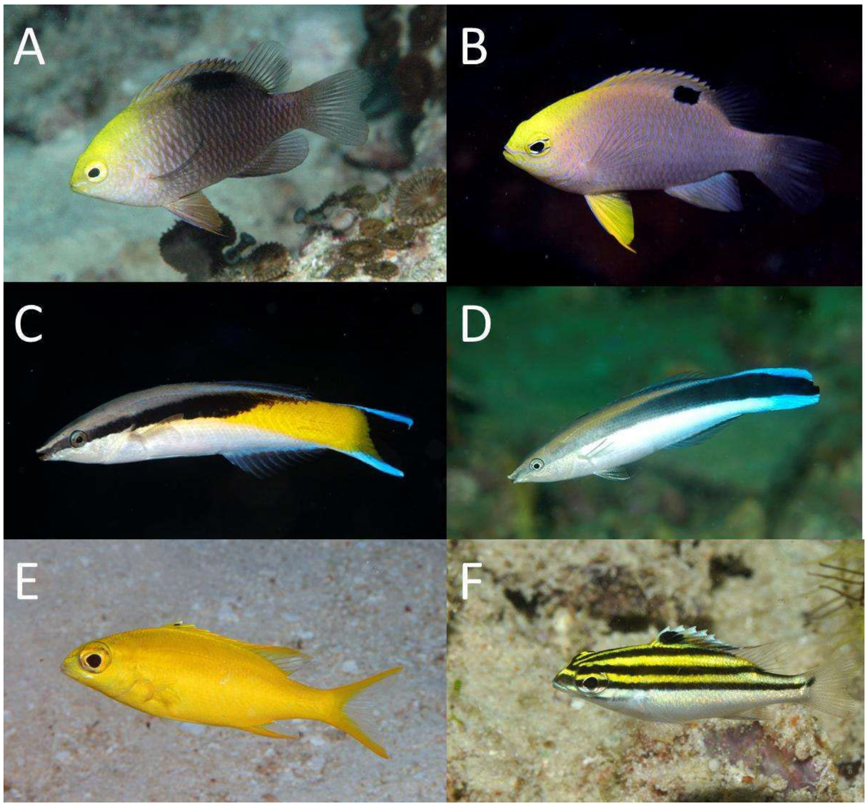

Figure 50. Localized colour variation in three species of Fijian reef fish with Fiji population shown in the left column and widespread Indo-Pacific equivalents in the right column: A-B Chrysiptera talboti (Pomacentridae); C-D Labroides dimidiatus (Labridae); E-F Scolopsis bilineatus (Nemipteridae), only juvenile (shown here) exhibit unusual yellow colour.

New species: Several confirmed or potential new species were collected or observed during the Lau MRAP survey and each is briefly discussed below.

Symphysanodon species (Symphysanodontidae) – This species, which appears to be undescribed, was photographed on the outer reef slope at site 11 (Vanua Vatu west) (Fig. 51). Several individuals were sighted at about 55 m depth. The species belongs to a family that usually inhabits depths below those frequented by scuba divers, known as the twilight zone. The species reaches a maximum size of at least 8 cm TL.

Figure 51. Symphysanodon species

Luzonichthys species (Serranidae) – Another undescribed species that was photographed on the steep outer reef slope at site 14 (Tavunasici west) (Fig. 52). It was relatively common, forming mixed aggregations with the Lori's Anthias (Pseudanthias lori) in about 50–60 m depth. The species reaches a maximum size of about 7 cm TL

Figure 52. Luzonichthys species

Pomacentrus species (Pomacentridae) – This undescribed species was previously misidentified as P. imitator (Whitley 1964), a similar fish now known to be confined to the Coral Sea (Fig. 53). The Fiji fish differs genetically and also has a slightly different colour pattern. The yellow iris ring is a useful diagnostic feature. It is common throughout Fiji and also the Tonga Archipelago, inhabiting the steep walls of large coral formations in lagoons and also adjacent to outer reef slopes in about 5–30 m depth. A new species description is currently being prepared by the authors and geneticist Dian Pertiwi. The species reaches a maximum size of about 10 cm TL. It was common at most sites during the Lau MRAP survey. Although no specimens were collected, it is well represented in collections at the Royal Ontario Museum, U.S. National Museum, and the Western Australian Museum.

Figure 53. Pomacentrus species

Enneapterygius species (Tripterygiidae) – Several specimens of this apparent new triplefin were collected at sites 17 and 18 (Olorua south and west). It is characterized by a reddish overall coloration with white saddles on the back, narrow white bars on the belly, and especially the large pale-edged dark spots covering the pectoral-fin base (Fig. 54). It is a secretive species that occurs in wave-exposed areas of the outer reef in 2–5 m depth. It reaches a maximum size of at least 3 cm TL.

Figure 54. Enneapterygius species

Grallenia species (Gobiidae) – Two specimens of this tiny (to 11.4 mm SL), inconspicuous goby were collected from a sand bottom in 30–35 m depth (Fig. 55). It belongs to a poorly known genus that contains two previously described species and several new taxa that are currently being studied by the authors. There are now at least five additional new species from the western Pacific, including the Lau fish, which will be named G. lauensis in our forthcoming publication. Although small in stature, the members of this genus are easily separated on the basis of their amount of body scales, presence or absence of head pores, and fin-ray counts.

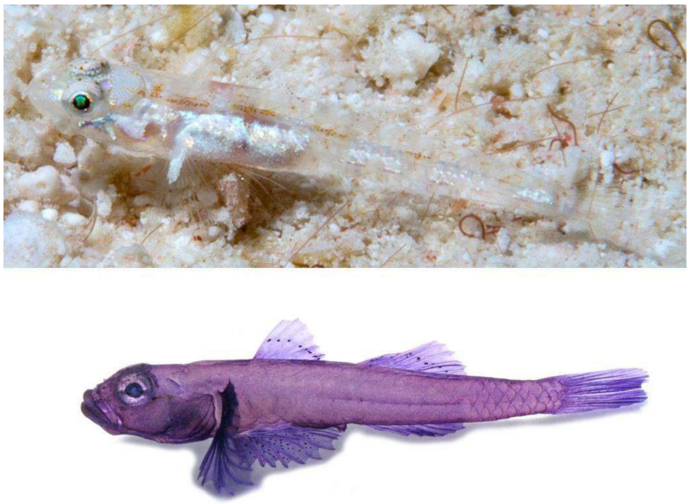

Figure 55. Grallenia species

Vanderhorstia species (Gobiidae) – No specimens were collected, but this species was photographed in the lagoon at site 23 (Karoni Lagoon), where it was relatively abundant on sandy substrate (Fig. 56). It appears to be the same undescribed species that was illustrated by Allen and Erdmann (2012, p. 892) and is apparently widespread in the Western Pacific, including Bali, East Timor and the Ryukyu Islands. It inhabits sand bottoms at depths between 1 m and 15 m and is reported to attain 6 cm TL.

Figure 56. Vanderhorstia species

Discussion

Conservation observations

Due to the short-term nature of the MRAP survey, it is difficult to gather definitive information regarding the overall abundance of individual species. Based on the divers' considerable experience at numerous locations across the Indo-Pacific, however, they noted a general paucity of sharks and a few other large fish, such as groupers, which indicate possible over-fishing.

Certainly, consideration should be given to protecting the remaining shark populations. Although the divers did observe sharks on a regular basis, the numbers were relatively low, with the exception of the Whitetip Reef Shark (*Triaenodon obesus*). Although they do not have any baseline data for Lau shark populations, the numbers observed during this survey indicate that stocks are generally low, particularly with regard to grey reef and silvertip sharks (*Carcharinus amblyrhynchos* and *C. albimarginatus*). Shark populations have been decimated by Asian fishing vessels, operating both legally and illegally, in many areas of the Indo-Pacific. Shark populations are extremely fragile and intense fishing over a relatively short period (even just a single month) can inflict considerable harm due to the territoriality of reef sharks, their slow growth rate, and low fecundity.

Our observations also indicate that both the Napoleon wrasse (*Cheilinus undulatus*) and bumphead parrotfish (*Bolbometopon muricatum*) were relatively rare, compared to other parts of the Central Pacific (e.g. Phoenix Islands). However, without baseline data, it is difficult to assess the current population levels and the need for conservation measures in the Lau Group. Stocks of both species are severely depleted over much of their Indo-Pacific range, a consequence of their high value in the live-fish trade associated with the restaurant industry in South-east Asia, particularly with regard to the Napoleon wrasse. As more easily accessed fishing grounds in the Philippines and Indonesia are being depleted, there is more pressure on outlying regions to supply the demand for this fish. Although the Napoleon wrasse was observed at 10 sites, they were usually single individuals or just a few fish at most. The bumphead parrotfish was seen at only a single site during the Lau survey. These observations are in marked contrast to the 20–25 Napoleon wrasse per dive and large shoals of bumphead parrotfish that were observed by GRA at the Phoenix Islands during a month-long survey in 2002. Commercially targeted fish

The true picture

Anyone would attest that good data are an integral part of effective decision-making to ensure resources will be available for future generations. With this in mind, the team made a comparison of reef locations surrounding inhabited and uninhabited islands, together with isolated reefs.

Though the targeted commercial fish populations were intact in isolated reefs, the inhabited island reefs were heavily exploited. The most common targeted species across the islands were the surgeons, snappers, parrotfish, breams, and jacks. The targeted fish abundance and densities were similar, but the biomass tipped for the isolated reefs in comparison to reefs around inhabited islands. The impact of over-exploitation and harvesting pressure on fish abundances and biomass was obvious. In addition, the behavior patterns of fish reacting to divers were incongruent. The divers swam into shoals of barracudas, unicorn fish, coral trout and pelagic dogtooth fish in isolated reefs, but were deprived of the same experience in inhabited island reefs. Fish sizes are smaller in the islands.

Moving forward

The commercially targeted fish will continue to be harvested for local consumption, but there needs to be some management exerted over the export of fish from the islands. Right now, unregulated harvesting is set to rise rapidly to meet market demands, threatening the fishery with collapse. Our people need to be educated and better informed of ways to maintain a healthy ecosystem and a healthy balance of diversity. Education will help shift mind-sets and attitudes, encouraging sustainable means of wildlife harvest and extraction. Alternative non-extractive means of income generation could be explored, in particular ecotourism of the rich biodiversity and pristine reefs in the area. Community management planning will need to be organized in order to address existing issues and concerns. Partnership at local, national and international levels is crucial in an MRAP process to enable access to experts who will deliver information that makes sense to the communities and enables them to make effective and efficient decisions.

Chapter 4: Sea cucumber fishery surveys

Schannel van Dijken and Tiko Lesi

Abstract

The objective of the sea cucumber study was to conduct a follow-up assessment on the status of sea cucumbers in the Lau Group after a previous 2013 study. The results, detailed in this report, will be used to help advise managers on the management of the Lau Group sea cucumber fishery.

A total of 63 individual sea cucumbers belonging to 15 of the 27 species of sea cucumbers that are found in Fiji waters were recorded in this assessment. The assessment also recorded five additional sea cucumber species (spiky red fish, surf red fish, chalk fish, white snake fish and dragon fish) that were not observed in the 2013 assessment. Tiger fish (*B. argus*) and amber fish (*T.anax*) (both are medium value species) were the most frequently encountered species with densities of about 5 indha-1. These species were particularly in high density in the Tavunisici and Navatu sites. Flower fish (*P. graeffei*) (medium value), which was the only species considered healthy in 2013, had an average density of 0.92 indha-1 which was lower than 2013. No sea cucumber were observed in two sites (Moala and Cakau Vate).

Overall, average densities of all species across the Lau Group were extremely low, even when compared to Pacific Community (SPC) Regional indicators. Densities were below the suggested threshold of 10–50 indha-1 that is required to avoid reproductive failure (Bell, Purcell and Nash, 2008). These results have shown an urgent need for effective management of the sea cucumber fishery in the Lau Group, and this study includes several recommendations for the Lau Group communities and Ministry of Fisheries to consider.

- **Consider implementing a complete and temporary halt in harvesting** to enable stocks to rebuild, so that a fishery can exist in the future. This strategy is ideal, followed by the recommendations below.
    - **Mandatory ban of UBA operations** – this fishing method is detrimental for all coastal fisheries resources, as well as to the health of fishers utilising the method.
    - **Seasonal closures on fishing sea cucumbers** to allow the stocks to recover from harvesting periods. The status of stock will need to be monitored frequently in order to determine when to open and close the fishery.
    - **Endorsement and implementation of the sea cucumber management plan draft.** The plan should include guidelines for harvest size limit, licensing for processing and fishing, and fishery data submission to the Ministry of Fisheries.
    - **Review export size limit regulations** to reflect mature size length for each sea cucumber species.

Introduction

Bêche-de-mer is the well-known trade name for dried sea cucumber, and it is one of Fiji's oldest trade commodities. Trading began in the early 1800s at the closing of the sandalwood trade boom, when traders gathered sea cucumber to supplement sandalwood cargo (Ram, Chand and Southgate 2016). Historical sea cucumber exports in Fiji follow typical boom and bust cycles. In recent years, sea cucumber export has shown some increase, but production volume today is less than half of that four decades ago. Today the sea cucumber fishery is Fiji's second most important commercial fishery, with the highest average export price for sea cucumber compared to other Pacific Islands (Purcell 2014). The main market for sea cucumber trade is Asia, where the product is considered a delicacy. Since 2003, the estimated average annual income obtained by all households involved in the fishery was FJD 10 million (Pakoa et al. 2013). Sea cucumber not only provides a source of income for Fijian people, but also a food source in the form of certain species such as sandfish (*H. scabra*).

Sea cucumbers are harvested by gleaning, snorkeling and free diving within Fiji's shallow water lagoons and reefs. Given the high value of sea cucumber as a coastal commodity, many fishers use underwater breathing apparatus (UBA) for commercial fishing in deeper water habitats (Ram, Chand and Southgate 2016). Commercial-scale UBA fishing harms sea cucumber stocks, kills other coastal species caught as by-catch, and affects the social and financial lives of fishers using unsafe gear and diving methods. UBA operations cost Fiji about FJD 5.8 million from 2012 to 2014 due to the use of unsafe UBA gear, and dozens of young divers sustained injuries or died (Lalavanua, Mangubhai and Purcell 2017).

A total of 27 sea cucumber species can be found in Fiji's coastal waters (Friedman et al. 2010). The latest sea cucumber assessment in 2013 recorded a total of 21 species in Fiji's waters, 13 of which were found in Lau (Table 16).

Table 16: List of the 27 sea cucumber species found in Fiji's waters and its presence (+) during Fiji's sea cucumber assessment and particularly that of Lau Group in 2013 (Source: Pakoa, et al. 2013)

SCIENTIFIC NAME	ENGLISH NAME	FIJIAN NAME	FIJI (2013)	LAU GROUP 2013
Actinopyga echinites	Deepwater redfish	Tarasea	+	
Actinopyga flammea	Spiky redfish	Tarasea		
Actinopyga lecanora	Stone fish	Dritabua	+	
Actinopyga mauritiana	Surf redfish	Tarasea	+	
Actinopyga miliaris	Hairy blackfish	Dri	+	+
Actinopyga palauensis	Deepwater black fish	Dri ni cakau		
Bohadschia argus	Tiger fish	Tiga	+	+
Bohadschia similis	Chalk fish	Mudra	+	
Bohadschia vitiensis	Brown sandfish	Vula	+	+
Holothuria atra	Lolly fish	Loliloli	+	+
Holothuria coluber	Snake fish	Samu ni uti	+	
Holothuria coronopertusa	Loli's mother	Tina ni loli		
Holothuria edulis	Pink fish	Lolipiqi	+	+
Holothuria fuscogilva	White teatfish	Sucuwalu	+	+
Holothuria fuscopunctata	Elephant trunkfish	Tinani dairo	+	+
Holothuria impatients	Slender sea cucumber			
Holothuria leucospilota	White snakefish			
Holothuria lessoni	Golden sand fish	Dairo kula		
Holothuria scabra	Sand fish	Dairo	+	
Holothuria whitmaei	Black teatfish	Loaloa	+	+
Pearsonothuria graeffei	Flower fish	Senikau	+	+
Stichopus chloronotus	Green fish	Barasi	+	+
Stichopus hermanni	Curry fish	Lauleva	+	+
Stichopus horrens	Dragon fish	Katapila	+	
Stichopus vastus	Brown curryfish	Laulevu	+	
Thelenota ananas	Prickly red fish	Sucudrau	+	+
Thelenota anax	Amber fish	Basi	+	+

The 2013 assessment was conducted by Fiji's Ministry of Fisheries in collaboration with the Pacific Community (SPC), the Wildlife Conservation Society, the University of the South Pacific and other key stakeholders. Most sea cucumber densities recorded were low in comparison to SPC regional density indicators (Pakoa et al. 2013). Within the Lau Group, the only exception was flower fish (*P. graeffei*) and pink fish (*H. edulis*), mainly in the Totoya and Vanuabalavu sites (Jupiter, Saladrau and Vave 2013).

Guidelines for harvesting sea cucumbers were set up by the Ministry of Fisheries in 1984 (Lalavanua, Tuinasavusavu and Seru 2014), setting out a ban on using UBA to prevent underwater incidents (Ram, Chand and Southgate 2016). The Permanent

Secretary can, however, allow the use of UBA upon request from certified divers and a fisher with a valid inshore fishing license, a valid license to operate UBA and a valid safety license (Pakoa et al. 2013). In 1988, additional measures were imposed to restrict harvest, including a minimum export size limit of 76 mm for all sea cucumber species (Lalavanua, Mangubhai and Purcell 2017). There has not been any review of these regulations or any new policies for sea cucumber since 1988 but there is a sea cucumber management plan for Fiji in draft.

Fiji has traditional fisheries management areas called *iqoliqoli* in communities that assist in sustainably managing sea cucumber stocks. The first fisheries management area established within the Lau group was in 1992 at Vuaqava village, and this was followed by another at Tuvuca village in 2000. Additional *iqoliqoli* were set up in Lau between 2007 and 2016 (Lau Province 2018). Field officers are stationed at these villages to help assist communities.

Results of the 2013 sea cucumber assessment showed sea cucumber being threatened by overexploitation, revealing a great need to review management measures. Other coastal species were also being targeted by UBA operations, which may affect their health status (Pakoa et al. 2013). Recommendations put forth by the assessment report have, however, not yet been implemented by the Fiji government, which relates highly to the results found in this follow-up study.

Methods

Twenty-eight sites at 11 locations were selected in the Lau Group (Cakau Lekaleka, Cakau Vate, Karoni Island, Matuku Island, Moala, Navatu, Navatu reef, Olorua, Tavunasici, Totoya, Vanua Vatu) to carry out the assessment of sea cucumbers (Table 17). Four of these locations were also assessed in 2013, namely that of Matuku island, Moala, Totoya and Vanua Vatu.

The assessment was conducted on 5–16 May 2017. The method used was a belt transect (dive) of about 40 metres in length and 2 metres wide, covering an estimated area of 80 m2. The transects were laid within the lagoons, outer reefs and channels within a depth range of 1 to 50 metres. The duration of each dive ranged from 60 to 85 minutes. (Note: This method was different from 2013 where it was both manta and transects 1 m x 40 m).

During the assessment, other observations were recorded, such as habitat coverage, fish and other invertebrates, particularly that of giant clams. The data collected were entered into Microsoft Excel for storage and analysis.

Each location had a range of 1 to 3 sites, depending on its habitat. Each location had belt transects that ranged from 7 to 54, where each transect measured out to be 80 m2. The total estimated area covered by the assessment was 27,520 m2 (2.75 ha). The areas covered per site are detailed below. The locations with the highest area coverage were Navatu and Totoya at 4,320 m2 (0.43 ha). Navatu reef had the lowest area coverage of 560 m2 (0.06 ha) (Table 17).

Table 17: Details of number of sites and transects conducted for each surveyed location

Locations	No. of sites	No. of Transects	Area surveyed (m2)	Area surveyed (ha)
Cakau Lekaleka	1	16	1,280	0.13
Cakau Vate	1	13	1,040	0.10
Karoni Island	3	36	2,880	0.29
Matuku Island	3	40	3,200	0.32
Moala	3	18	1,440	0.14
Navatu	3	54	4,320	0.43
Navatu Reef	2	7	560	0.06
Olorua	3	29	2,320	0.23
Tavunasici	3	36	2,880	0.29
Totoya	3	54	4,320	0.43
Vanua Vatu	3	41	3,280	0.33
Total	**28**	**344**	**27,520**	**2.75**

Results

Species presence and occurrence

A total of 63 individual sea cucumber belonging to 15 species were recorded in the assessment (Table 18). Amber fish (*T. anax*) and tiger fish (*B. argus*) were the most recorded species of 19 and 16 specimens respectively **(Fig. 57)**. Prickly red fish was the third most common species, followed by pink fish (*H. edulis*) and white teatfish (*H. fuscogilva*). Other species counts were very low, from one to three specimens, as detailed in Table 18.

Figure 57: Amber fish (Left) and tiger fish (right) that were common in Lau Group

Navatu and Tavunasici had the highest number of sea cucumber recorded. Navatu had a high number of amber fish (*T. anax*) and Tavunasici a high number of tiger fish (*B. argus*). Cakau Lekaleka was the only site where a dragon fish (*S. horrens*) and spiky red fish (*A. flammea*) were recorded. Green fish (S. chloronotus) and black teatfish (*H. whitmaei*) were only recorded in Tavunasici. Surf red fish (*A. mauritiana*) was only recorded in Olorua. Lolly fish (*H. atra*), a very common sea cucumber, and hairy black fish (A. miliaris) were only found in Navatu. Matuku Island had the highest number of species recorded while no sea cucumber were recorded in Moala and Cakau Vate sites. Sand fish, an important species in Fijians' diet, was not observed in any of the sites.

In comparison to the assessment in 2013 (Table 19), five new species were recorded, namely that of spiky red fish (*A. flammea*), surf red fish (*A. mauritiana*), chalk fish (*B. similis*), white snake fish (*H. leucospilota*) and dragon fish (*S. horrens*) (Table 4). Two of those species (spiky red fish and white snake fish) were not recorded in any of Fiji's waters in 2013.

On the other hand, three species that were observed in 2013 were not observed in this recent assessment. These were elephant trunkfish (*H. fuscopunctata*), curry fish (*S. hermanni*) and brown sandfish (*B. vitiensis*). Furthermore, four species that are known to be present in Fiji's waters that were not observed in 2013, were also not observed in 2017. These were deep water black fish (*A. palauensis*), loli's mother (*H. coronopertusa*), golden sandfish (*H. lessoni*) and slender sea cucumber (*H. impatients*).

Table 18: Count of sea cucumber species recorded by site

SEA CUCUMBER SPECIES	CAKAU LEKEL-EKE	KARONI ISLAND	MATUKU ISLAND	NAVATU	NAVATU REEF	OLORUA	TAVUNASICI	TOTOYA	VANUA VATU	TOTAL-SPECIES
Actinopyga Flammea	1									1
Actinopyga Mauritiana						1				1
Actinopyga Miliaris				1						1
Bohadschia Argus	3			2	1		7	2	1	16

Bohadschia Similis								1	1	2
Holothuria Atra					1					1
Holothuria Edulis		1	2				1			4
Holothuria Fuscogilva		1	1	2						4
Holothuria Leucospilota									1	1
Holothuria Whitmaei							1			1
Pearsonothuria Graeffei			1			1		1		3
Stichopus Chloronotus							3			3
Stichopus Horrens	1									1
Thelenota Ananas			1			2		2		5
Thelenota Anax		6	1	10					2	19
Total_Site	**5**	**8**	**6**	**15**	**2**	**4**	**12**	**6**	**5**	**63**

Table 19: List of species found in Fiji's waters (historical list) and their presence (+) during the 2013 and 2017 assessments

SCIENTIFIC NAME	ENGLISH NAME	FIJI ASSESSMENT (2013)	LAU GROUP (2013)	LAU GROUP 2017
Actinopyga echinites	Deepwater redfish	+		
Actinopyga flammea	Spiky redfish			+
Actinopyga lecanora	Stone fish	+		
Actinopyga mauritiana	Surf redfish	+		+
Actinopyga miliaris	Hairy blackfish	+	+	+
Actinopyga palauensis	Deepwater black fish			
Bohadschia argus	Tiger fish	+	+	+
Bohadschia similis	Chalk fish	+		+
Bohadschia vitiensis	Brown sandfish	+	+	
Holothuria atra	Lolly fish	+	+	+
Holothuria coluber	Snake fish	+		
Holothuria coronopertusa	Loli's mother			
Holothuria edulis	Pink fish	+	+	+
Holothuria fuscogilva	White teatfish	+	+	+
Holothuria fuscopunctata	Elephant trunkfish	+	+	
Holothuria impatients	Slender sea cucumber			
Holothuria leucospilota	White snakefish			+
Holothuria lessoni	Golden sand fish			
Holothuria scabra	Sand fish	+		
Holothuria whitmaei	Black teatfish	+	+	+
Pearsonothuria graeffei	Flower fish	+	+	+
Stichopus chloronotus	Green fish	+	+	+
Stichopus hermanni	Curry fish	+	+	

Stichopus horrens	Dragon fish	+		+
Stichopus vastus	Brown curryfish	+		
Thelenota ananas	Prickly red fish	+	+	+
Thelenota anax	Amber fish	+	+	+

Densities and abundance of species

Tiger fish (*B. argus*) and amber fish (*T. anax*) were the most frequently encountered species from the assessment, with densities of about five individuals per hectare. These two species are of high value in the Asian market. All other sea cucumber species recorded were of low mean densities, ranging from 0.2 to 1 individual per hectare (Table 20).

Tiger fish was widely spread out among the sites with a presence of about 36%. It is also evident in its mean present density of 17 indha^{-1}. Lolly fish had a high estimated present mean density, mainly due to one site having one lolly fish observed.

Among the sites, Cakau Lekaleka and Tavunisici had a high density of tiger fish (*B. argus*) (Table 21). Green fish was only recorded in Tavunisici with an average density of about 11 indha^{-1}. In Navatu, the species with highest density was amber fish (*T. anax*) (*23 indha^{-1}*), while in Olorua it was prickly red fish (*T. annas*).

Table 20: Overall Lau Group sea cucumber mean densities (indha-1), standard errors (SE) and percentageage present in sites

SEA CUCUMBER SPECIES	OVERALL MEAN DENSITY	SE OVERALL MEAN	PRESENT MEAN DENSITY	SE PRESENT MEAN DENSITY	NO. SITES	NO. SITES PRESENT	% PRESENT
Actinopyga flammea	0.28	0.28	7.81		28	1	4
Actinopyga mauritiana	0.37	0.37	10.42		28	1	4
Actinopyga miliaris	0.25	0.25	6.94		28	1	4
Bohadschia argus	5.96	1.96	16.67	3.54	28	10	36
Bohadschia similis	0.53	0.37	7.38	0.43	28	2	7
Holothuria atra	1.49	1.49	41.67		28	1	4
Holothuria edulis	1.23	0.79	11.46	2.17	28	3	11
Holothuria fuscogilva	1.17	0.66	10.88	1.62	28	3	11
Holothuria leucospilota	0.32	0.32	8.93		28	1	4
Holothuria whitmaei	0.37	0.37	10.42		28	1	4
Pearsonothuria graeffei	0.92	0.52	8.56	1.94	28	3	11
Stichopus chloronotus	1.12	0.82	15.63	7.37	28	2	7
Stichopus horrens	0.28	0.28	7.81		28	1	4
Thelenota ananas	1.46	0.83	13.66	1.88	28	3	11
Thelenota anax	5.36	2.75	25.26	9.62	28	6	21

Note: Present density looks at the average density only of sites where sea cucumbers were recorded, no. sites present is the number of sites where the species was recorded

Table 21: Sea cucumber mean densities (indha-1) by surveyed location

SEA CUCUMBER SPECIES	CAKAU LEKELE-KE	KARONI IS.	MATUKU IS.	NAVATU	NAVATU REEF	OLORUA	TAVUNI-SICI	TOTOYA	VANUA VATU
Actinopyga flammea	7.81								
Actinopyga mauritiana						3.47			
Actinopyga miliaris				2.31					
Bohadschia argus	23.44			4.63	15.63		24.31	4.63	3.79
Bohadschia similis								2.31	2.60
Holothuria atra					20.83				
Holothuria edulis		2.78	5.21				3.47		
Holothuria fuscogilva		2.78	3.47	4.63					
Holothuria leucospilota									2.98
Holothuria whitmaei							3.47		
Pearsonothuria graeffei			3.47			2.78		2.31	
Stichopus chloronotus							10.42		
Stichopus horrens	7.81								
Thelenota ananas			3.47			5.56		4.63	
Thelenota anax		16.67	3.47	23.15					6.76

Determining healthy mean densities and endangered species

The SPC Pacific regional reference density is a useful tool to determine the health status of the sea cucumber in the Lau Group. When compared with regional reference densities, all sea cucumber species recorded from the Lau Group in this assessment are of low density. Comparison of the estimated densities to the past assessment in 2013 showed an increase in density for one species (amber fish (*T. anax*). Five other species observed in this assessment in low densities were not observed in 2013 (Table 22).

Table 22: Recent assessment densities (indha-1) compared to past assessment, SPC reference indicators and IUCN listing

SEA CUCUMBER SPECIES	OVERALL MEAN DENSITY 2017	DENSITY 2013 ASSESSMENT[1]	REGIONAL REFERENCE DENSITY[2]	IUCN LISTING[3]
Actinopyga Flammea	0.28			
Actinopyga Mauritiana	0.37			VE
Actinopyga Miliaris	0.25	3.09	150	VE
Bohadschia Argus	5.96	3.09	120	
Bohadschia Similis	0.53			
Bohadschia Vitiensis		0.08		
Holothuria Atra	1.49	1.54	5600	
Holothuria Edulis	1.23	3.09		

Holothuria Fuscogilva	1.17	0.08	20	VE
Holothuria Fuscopunctata		2.29		
Holothuria Leucospilota	0.32			
Holothuria Whitmaei	0.37	3.09	50	EE
Pearsonothuria Graeffei	0.92	55.56	100	
Stichopus Chloronotus	1.12	0.84	3500	
Stichopus Hermanni		0.23		
Stichopus Horrens	0.28			
Thelenota Ananas	1.46	0.23	30	EE
Thelenota Anax	5.36	1.54	?	

[1]*Lau Combined Survey (2013),* [2]*SPC Regional reference (2013),* [3]*International Union for Conservation of Nature-Red Listing: VE – Vulnerable to extinction, EE-Endangered with extinction*

Three of the low-density sea cucumber species, namely surf red fish (*A. mauritiana*), hairy black fish (*A. miliaris*) and white teat fish (*H. fuscogilva*), are listed as vulnerable to extinction under the International Union for Conservation of Nature (IUCN) red listing. Two other species are listed as endangered with extinction: black teat fish (*H. whitmaei*) and prickly red fish (*T. ananas*).

Discussion

A positive outcome of this assessment was that it recorded five additional sea cucumber species (spiky red fish, surf red fish, chalk fish, white snake fish and dragon fish) that were not recorded in the past assessment in the Lau Group. This may be due to the fact that not all 2013 sites were reassessed, and there were some new sites in the recent assessment. However, for reassessed sites where these new species were recorded, it may be a sign of shift to other targeted species that these species have resurfaced.

The greatest concern is that no sandfish (*H. scabra*) were recorded from this assessment. This is a species that is being banned from export due to its local diet importance. Three species that were recorded in the past, elephant trunkfish (*H. fuscopunctata*), curry fish (*S. hermanni*) and brown sandfish (*B. vitiensis*), were also not observed. This may be a sign of overfishing of these species, as according to the 2013 perception survey, brown sandfish was one of the commonly caught species by Lau fishers (Jupiter, Saladrau and Vave 2013) and there was no existing regulation on the amount harvested. Lollyfish (*H. atra*) and surf red fish (*A. mauritiana*) were other common species recorded from Lau catches. Both species were only of one specimen in Navatu and Olorua respectively.

There were two sites without any observed sea cucumbers: Moala and Cakau Vate. In 2013, Moala had an average sea cucumber density of 25 indha^{-1} from belt transect and 7 indha^{-1} from manta tows (Jupiter, Saladrau and Vave 2013). Such a decline in sea cucumber in Moala raises great concern over whether the six *iqoliqoli* established in Moala from 2009 to 2012 are working or being monitored but the Matuku *iqoliqoli* may have helped in keeping the high diversity of species recorded in Matuku Island.

Average densities of all species across the Lau Group were very low, even when compared to SPC Regional indicators. Five of the low-density species are red-listed under IUCN as vulnerable to extinction and endangered with extinction. These are the surf red fish (*A. mauritiana*), black fish (*A. miliaris*), white teatfish (*H. fuscogilva*), black teatfish (*H. whitmaei*) and prickly red fish (*T. ananas*). The white teatfish and black teatfish were also reported by Lau fishers as the hardest to find species (Jupiter, Saladrau and Vave 2013).

All species densities were below the suggested threshold of 10–50 indha^{-1} to avoid reproductive failure (Bell, Purcell and Nash 2008). Only tiger fish was widely spread across the sites (*B. argus*). The highest average density recorded was 5 indha^{-1} for tiger fish (*B. argus*) and amber fish (*T. anax*). These species were particularly high in density in the Tavunisici and Navatu sites. Both sites were described as having healthy reef of 40–70% coral coverage. Flower fish (medium value), which was the only species considered healthy in 2013, had an average density of 0.92 indha^{-1}, another indication of overfishing of certain species.

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Annex

Table A.1 Full list of species recorded during the Lau Island MRAP in May 2017

FAMILY	GENUS / SPECIES
	FISH
CARCHARHINIDAE	Carcharhinus albimarginatus (Rüppell, 1837)
	C. amblyrhynchos (Bleeker, 1856)
	C. melanopterus (Quoy and Gaimard, 1824)
	Triaenodon obesus (Rüppell, 1835)
DASYATIDIDAE	Dasyatis kuhlii (Müller and Henle, 1841)
	Taeniura meyeni (Müller and Henle, 1841)*
MYLIOBATIDAE	Aetobatus narinari (Euphrasen, 1790)
MURAENIDAE	G. javanicus (Bleeker, 1865)
CONGRIDAE	Gorgasia species
	Heteroconger hassi (Klausewitz and Eibl-Eibesfeldt, 1959)
SYNODONTIDAE	Synodus binotatus Schultz, 1953
	S. dermatogenys Fowler, 1912
	S. rubromarmoratus Russell and Cressy, 1979
	S. variegatus (Lacepede, 1803)
HEMIRAMPHIDAE	Hyporhamphus affinis (Günther, 1866)
HOLOCENTRIDAE	Myripristis berndti Jordan and Evermann, 1902
	M. kuntee Valenciennes, 1831
	M. violacea Bleeker, 1851
	M. vittata Valenciennes, 1831
	Neoniphon argenteus (Valenciennes, 1831)
	N. opercularis (Valenciennes, 1831)
	N. sammara (Forsskål, 1775)
	Sargocentron caudimaculatum (Rüppell, 1835)
	S. diadema (Lacepède, 1802)
	S. melanospilos (Bleeker, 1858)
	S. spiniferum (Forsskål, 1775)
	S. tiere (Cuvier, 1829)
AULOSTOMIDAE	Aulostomus chinensis (Linnaeus, 1766)
FISTULARIIDAE	Fistularia commersoni Rüppell, 1835
SYNGNATHIDAE	Corythoichthys flavofasciatus (Rüppell, 1838)
	Dunckerocampus naia Allen & Kuiter, 2004
SCORPAENIDAE	Pterois antennata (Bloch, 1787)
	P. volitans (Linnaeus, 1758)
	Sebastapistes cyanostigma (Bleeker, 1856)
CARACANTHIDAE	Caracanthus maculatus (Gray, 1831)
	Caracanthus unipinna (Gray, 1831)
SYMPHYSANODONTI-DAE	Symphysanodon species
SERRANIDAE	Anyperodon leucogrammicus (Valenciennes, 1828)
	Belonoperca chabanaudi Fowler and Bean, 1930
	Cephalopholis argus Bloch and Schneider, 1801
	C. leopardus (Lacepède, 1802)
	C. polleni (Bleeker, 1868)
	C. sexmaculata Rüppell, 1828
	C. spiloparaea (Valenciennes, 1828)
	C. urodeta (Schneider, 1801)
	Epinephelus areolatus (Forsskål, 1775)
	E. hexagonatus (Bloch and Schneider, 1801)
	E. macrospilos (Bleeker)
	E. maculatus (Bloch, 1790)
	E. polyphekadion (Bleeker, 1849)
	Grammistes sexlineatus (Thünberg, 1792)
	Gracila albomarginata (Fowler and Bean, 1930)

	Liopropoma multilineatum Lubbock & Randall, 1978*
	L. susumi (Jordan & Seale, 1906)*
	Luzonichthys cf williamsi Mark photo deep
	Plectranthias longimanus (Weber, 1913)
	P. winniensis (Tyler, 1966)
	Plectropomus laevis (Lacepède, 1802)
	P. leopardus (Lacepède, 1802)
	Pseudanthias bicolor (Randall, 1979)
	P. carlsoni Randall & Pyle, 2001
	P. cooperi (Regan, 1902)
	P. hypselosoma Bleeker, 1878
	P. lori (Lubbock & Randall, 1976)
	P. pascalus (Jordan & Tanaka, 1927)
	P. pleurotaenia (Bleeker, 1857)
	P. squamipinnis (Peters, 1855)
	P. ventralis (Randall, 1979)
	Serranocirrhitus latus Watanabe, 1949
	Variola albimarginata Baissac, 1953
	V. louti (Forsskål, 1775)
PSEUDOCHROMIDAE	Cypho purpurascens (De Vis, 1884)
	Lubbockichthys sp.
	Pictichromis porphyrea (Lubbock & Goldmanm 1974)
	P. jamesi Schultz, 1943
	P. rosae Schultz, 1943
PLESIOPIDAE	Calloplesiops altivelis (Steindachner, 1903)
CIRRHITIDAE	Cirrhitichthys falco Randall, 1963
	Cirrhitus pinnuatus (Forster, 1801)
	Neocirrhites armatus Castelnau, 1873
	Paracirrhites arcatus (Cuvier, 1829)
	P. forsteri (Schneider, 1801)
	P. hemistictus(Gunther, 1874)
OPISTOGNATHIDAE	O. “wassi” Smith-Vaniz (ms)
PRIACANTHIDAE	Heteropriacanthus cruentatus (Lacepède, 1801)
	Priacanthus blochii Bleeker, 1853
	Priacanthus hamrur (Forsskål, 1775)
APOGONIDAE	C. artus Smith, 1961
	C. macrodon Lacepède, 1801
	C. quinquelineatus Cuvier, 1828
	F. vaiulae (Jordan and Seale, 1906)
	Ostorhinchus angustatus (Smith and Radcliffe, 1911)
	O. apogonides (Bleeker, 1856)
	O. bryx (Fraser, 1998)
	O. cyanosoma (Bleeker, 1853)
	O. nigrofasciatus (Schultz, 1953)
	O. novemfasciatus (Cuvier, 1828)
	O. taeniophorus (Regan, 1908)
	Pristiapogon exostigma (Jordan and Starks, 1906)
	P. fraenatus (Valenciennes, 1832)
	P. kallopterus Bleeker, 1856
	Siphamia fraseri Gon & Allen, 2012
	T. fucata (Cantor, 1850)
MALACANTHIDAE	H. starcki Randall and Dooley, 1974
	Malacanthus brevirostris Guichenot, 1848
ECHENEIDAE	Echeneis naucrates Linnaeus, 1758
CARANGIDAE	Carangoides bajad (Forsskål, 1775)
	C. ferdau (Forsskål, 1775)
	C. orthogrammus (Jordan and Gilbert, 1882)
	C. plagiotaenia Bleeker, 1857
	C. lugubris (Poey, 1860)
	C. melampygus Cuvier, 1833
	D. macarellus (Cuvier, 1833)
	Elegatis bipinnulatus (Quoy and Gaimard, 1825)

	Scomberoides tol (Cuvier, 1832)
LUTJANIDAE	Aphareus furca (Lacepède, 1802)
	Aprion virescens Valenciennes, 1830
	Lutjanus argentimaculatus (Forsskål, 1775)
	L. bohar (Forsskål, 1775)
	L. ehrenburgi (Peters, 1869)
	L. fulvus (Schneider, 1801)
	L. gibbus (Forsskål, 1775)
	L. kasmira (Forsskål, 1775)
	L. monostigma (Cuvier, 1828)
	L. semicinctus Quoy and Gaimard, 1824
	Macolor macularis Fowler, 1931
	M. niger (Forsskål, 1775)
	Paracaesio sordidus Abe & Shinohara, 1962*
CAESIONIDAE	Caesio caerulaurea Lacepède, 1802
	C. lunaris Cuvier, 1830
	C. teres Seale, 1906
	P. lativittata Carpenter, 1987
	P. marri Schultz, 1953
	P. pisang (Bleeker, 1853)
	P. tile (Cuvier, 1830)
	P. trilineata Carpenter, 1987
HAEMULIDAE	P. chaetodontoides (Lacepède, 1800)
LETHRINIDAE	Gnathodentex aurolineatus Lacepède, 1802
	Gymnocranius grandoculus (Valenciennes, 1830)
	G. sp. (Carpenter & Allen, 1989)
	Lethrinus atkinsoni Seale, 1909
	L. erythracanthus Valenciennes, 1830
	L. harak (Forsskål, 1775)
	L. miniatus (Forster, 1801)
	L. obsoletus (Forsskål, 1775)
	L. olivaceous Valenciennes, 1830
	Monotaxis grandoculis (Forsskål, 1775)
	M. heterodon (Bleeker, 1854)
NEMIPTERIDAE (3 spp.)	Pentapodus aureofasciatus Russell, 2001
	Scolopsis bilineatus (Bloch, 1793)
MULLIDAE	Mulloidichthys flavolineatus (Lacepède, 1802)
	M. vanicolensis (Valenciennes, 1831)
	Parupeneus barberinoides (Lacepède, 1801)
	P. barberinus (Lacepède, 1801)
	P. crassilabris (Valenciennes, 1831)
	P. ciliatus (Lacepède, 1802)
	P. cyclostomus (Lacepède, 1802)
	P. multifasciatus Bleeker, 1873
	P. pleurostigma (Bennett, 1830)
PEMPHERIDAE	Pempheris oualensis Cuvier, 1831
KYPHOSIDAE	Kyphosus cinerascens (Forsskål, 1775)
	K. vaigiensis (Quoy and Gaimard, 1825)
	K. sp. (low, dark fins, silvery body)
CHAETODONTIDAE	Chaetodon auriga Forsskål, 1775
	C. baronessa Cuvier, 1831
	C. bennetti Cuvier, 1831
	C. citrinellus Cuvier, 1831
	C. ephippium Cuvier, 1831
	C. flavirostris Günther 1874
	C. kleinii Bloch, 1790
	C. lineolatus Cuvier, 1831
	C. lunula Lacepède, 1803
	C. lunulatus Quoy and Gaimard, 1824
	C. melannotus Schneider, 1801
	C. mertensii Cuvier, 1831
	C. ornatissimus Cuvier, 1831
	C. oxycephalus Bleeker, 1853

	C. pelewensis Kner, 1868
	C. plebeius Cuvier, 1831
	C. rafflesi Bennett, 1830
	C. reticulatus Cuvier, 1831
	C. semeion Bleeker, 1855
	C. speculum Cuvier, 1831*
	C. trifascialis Quoy and Gaimard, 1824
	C. ulietensis Cuvier, 1831
	C. unimaculatus Bloch, 1787*
	C. vagabundus Linnaeus, 1758
	Forcipiger flavissimus Jordan and McGregor, 1898
	F. longirostris (Broussonet, 1782)
	Hemitaurichthys polylepis (Bleeker, 1857)*
	Heniochus acuminatus (Linnaeus, 1758)
	H. chrysostomus Cuvier, 1831
	H. diphreutes Jordan, 1903
	H. monoceros Cuvier, 1831
	H. singularius Smith and Radcliffe, 1911
	H. varius (Cuvier, 1829)
POMACANTHIDAE	C. bicolor (Bloch, 1798)
	C. bispinosus (Günther, 1860)
	C. flavicauda Fraser-Brunner, 1933
	C. flavissima (Cuvier, 1831)
	C. multicolor Randall & Wass, 1974
	C. woodheadi Kuiter, 1998
	Genicanthus bellus Randall, 1975
	G. melanospilos (Bleeker, 1857)
	Genicanthus watanabei (Yasuda & Tominaga 1970)
	Paracentropyge multifasciatus (Smith and Radcliffe, 1911)
	Pomacanthus imperator (Bloch, 1787)
	Pygoplites diacanthus (Boddaert, 1772)
POMACENTRIDAE	A. sexfasciatus Lacepède, 1802
	A. vaigiensis (Quoy and Gaimard, 1825)
	Amblyglyphidodon aureus (Cuvier, 1830)
	A. curacao (Bloch, 1787)
	A. orbicularis (Hombron & Jacquinot, 1853)
	Amphiprion barberi Allen, Drew & Kaufman, 2008
	Amphiprion chrysopterus Cuvier, 1830
	A. pacificus Allen, Drew & Fenner, 2010
	A. perideraion Bleeker, 1855
	Chromis acares Randall & Swerdloff, 1973
	C. agilis Smith, 1960
	C. alpha Randall, 1988
	C. amboinensis (Bleeker, 1873)
	C. analis (Cuvier, 1830)
	C. atripectoralis Welander and Schultz, 1951
	C. atripes Fowler and Bean, 1928
	C. chrysura (Bliss, 1883)
	C. delta Randall, 1988
	C. elerae Fowler and Bean, 1928
	C. iomelas Jordan & Seale, 1906*
	C. lepidolepis Bleeker, 1877
	C. margaritifer Fowler, 1946
	C. retrofasciata Weber, 1913
	C. ternatensis (Bleeker, 1856)
	C. vanderbilti (Fowler, 1941)
	C. viridis (Cuvier, 1830)
	C. weberi Fowler and Bean, 1928
	C. xanthura (Bleeker, 1854)
	Chrysiptera biocellata (Quoy and Gaimard, 1824)
	C. caeruleolineata (Allen, 1973)
	C. leucopoma (Cuvier, 1830)
	C. starcki (Allen, 1973)

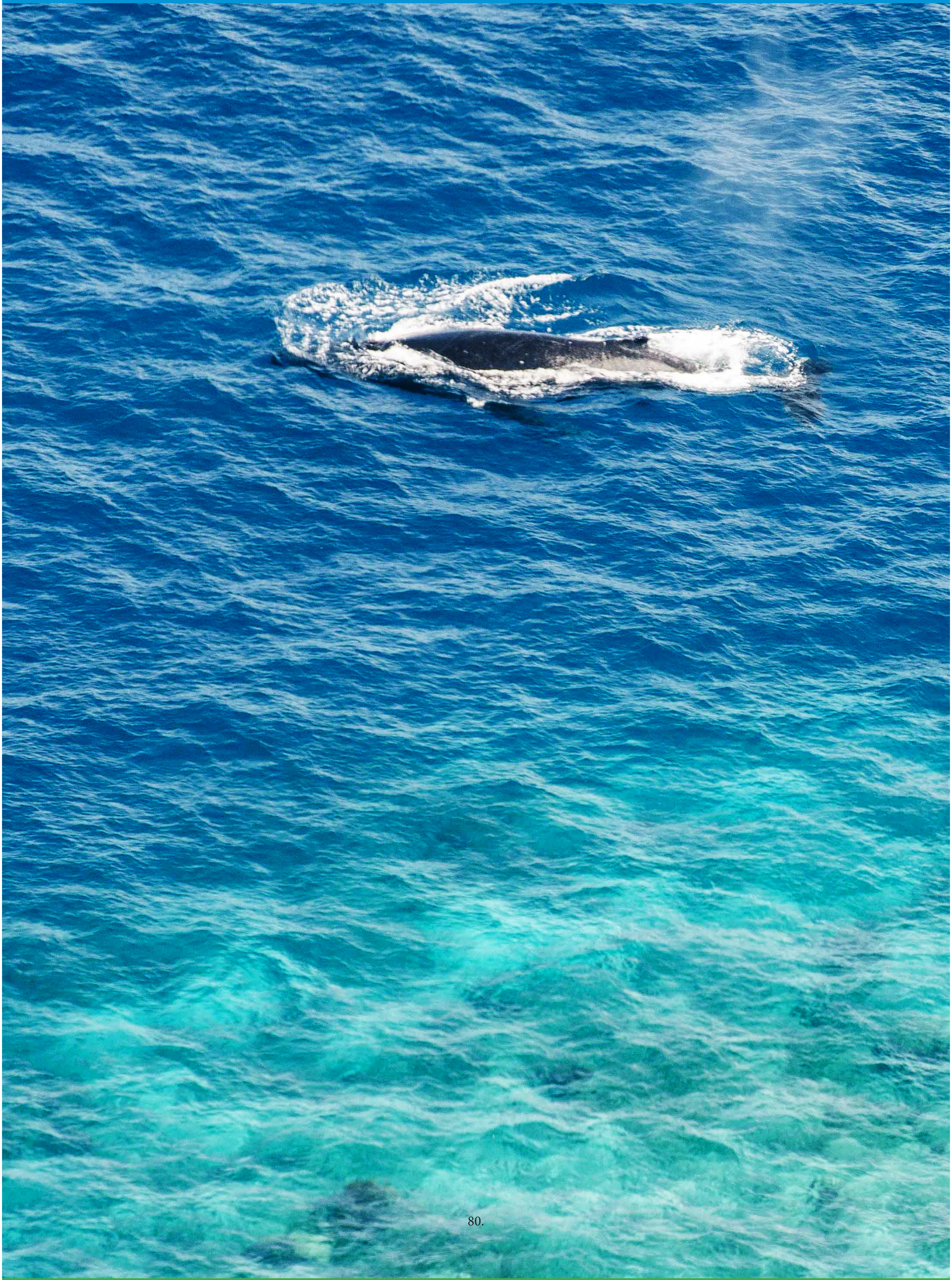
	C. talboti (Allen, 1975)
	C. taupou (Jordan & Seale, 1906)
	C. unimaculata (Cuvier, 1830)
	Dascyllus aruanus (Linnaeus, 1758)
	D. reticulatus (Richardson, 1846)
	D. trimaculatus (Rüppell, 1928)
	Neoglyphidodon carlsoni Allen, 195
	Neopomacentrus metallicus Jordan & Seale, 1906
	Plectroglyphidodon dickii (Liénard, 1839)
	P. imparipennis (Vaillant & Sauvage, 1875)
	P. johnstonianus Fowler & Ball, 1924
	P. lacrymatus (Quoy and Gaimard, 1824)
	Pomacentrus bankanensis Bleeker, 1853
	Pomacentrus callainus Randall, 2002
	Pomacentrus coelestis Jordan and Starks, 1901
	P. cf imitator (Whitley, 1964)
	P. maafu Allen & Drew, 2005
	P. microspilusAllen & Randall, 2005
	P. nigromarginatus Allen, 1973
	P. pavo (Bloch, 1878)
	P. spilotoceps Randall, 2002
	P. vaiuli Jordan and Seale, 1906
	Pomachromis richardsoni (Snyder, 1909)
	Stegastes albifasciatus (Schlegel and Müller, 1839)
	S. fasciolatus (Ogilby, 1889)
	S. nigricans (Lacepède, 1802)
	S. punctatus (Quoy & Gaimard, 1825)
LABRIDAE	Anampses caeruleopunctatus Rüppell, 1828
	A. geographicus Valenciennes, 1840
	A. melanurus Bleeker, 1857
	A. neoguinaicus Bleeker, 1878
	A. twistii Bleeker, 1856
	Bodianus anthioides (Bennett, 1831)
	B. axillaris (Bennett, 1831)
	B. bimaculatus Allen, 1973
	B. dictynna Gomon, 2006
	B. loxozonus (Snyder, 1908)
	B. mesothorax Schneider, 1801
	Cheilinus chlorourus (Bloch, 1791)
	C. fasciatus (Bloch, 1791)
	C. oxycephalus Bleeker, 1853
	C. trilobatus Lacepède, 1802*
	C. undulatus Rüppell, 1835
	Choerodon jordani (Snyder, 1908)
	C. punctatus Randall & Kuiter, 1989
	C. rubrimarginatus Randall, 1992
	C. scottorum Randall & Pyle, 1989 600 SPP
	Coris aygula Lacepède, 1802
	C. batuensis (Bleeker, 1856)
	C. gaimardi (Quoy and Gaimard, 1824)
	Epibulus insidiator (Pallas, 1770)
	Gomphosus varius Lacepède, 1801
	H. biocellatus Schultz, 1960
	H. hortulanus (Lacepède, 1802)
	H. marginatus (Rüppell, 1835)
	H. melasmapomus
	H. melanurus Bleeker, 1853
	H. claudiae
	H. prosopeion Bleeker, 1853
	H. trimaculatus Griffith, 1834
	Hemigymnus fasciatus Bloch, 1792
	H. melapterus Bloch, 1791
	Hologymnosus annulatus (Lacepède, 1801)

	H. doliatus Lacepède, 1801
	Iniistius celebicus (Bleeker, 1856)
	Labrichthys unilineatus (Guichenot, 1847)
	Labroides bicolor Fowler and Bean, 1928
	L. dimidiatus (Valenciennes, 1839)
	Labropsis alleni Randall, 1981
	L. australis Randall, 1981
	L. xanthonota Randall, 1981
	Macropharyngodon meleagris (Valenciennes, 1839)
	M. negrosensis Herre, 1932
	N. taeniourus (Lacepède, 1802)
	Oxycheilinus bimaculatus Valenciennes, 1840
	O. diagramma (Lacepède, 1802)
	O. unifasciatus (Streets, 1877)
	Pseudocheilinus evanidus Jordan and Evermann, 1902
	P. hexataenia (Bleeker, 1857)
	P. ocellatus Randall, 1999
	P. octotaenia Jenkins, 1901
	P. tetrataenia Schultz, 1960
	Pseudocoris aurantiofasciata Fourmanoir, 1971
	Pseudocoris yamashiroi (Schmidt, 1930)
	Pseudodax moluccanus (Valenciennes, 1840)
	Pseudojuloides cerasina Snyder, 1904
	Pteragogus cryptus Randall, 1981
	Stethojulis bandanensis (Bleeker, 1851)
	S. strigiventer (Bennett, 1832)
	Thalassoma amblycephalum (Bleeker, 1856)
	T. hardwicke (Bennett, 1828)
	T. lunare (Linnaeus, 1758)
	T. lutescens (Lay & Bennett, 1839)
	T. nigrofasciatum Randall, 2003
	T. purpureum (Forsskål, 1775)
	T. quinquevittatum (Lay and Bennett, 1839)
	W. nigropinnata (Seale, 1901)
SCARIDAE	Bolbometopon muricatum (Valenciennes, 1840)
	Calotomus spinidens (Quoy & Gaimard, 1824)
	Cetoscarus ocellatus
	Chlorurus bleekeri (de Beaufort, 1940)
	C. microrhinos (Bleeker, 1854)
	C. sordidus (Forsskål, 1775)
	Hipposcarus longiceps (Bleeker, 1862)
	Scarus altipinnis (Steindachner, 1879)
	S. chameleon Choat and Randall, 1986)
	S. dimidiatus Bleeker, 1859
	S. forsteni (Bleeker, 1861)
	S. frenatus Lacepède, 1802
	S. globiceps Valenciennes, 1840
	S. longipinnis Randall & Choat, 1980
	S. niger Forsskål, 1775
	S. oviceps Valenciennes, 1839
	S. psittacus Forsskål, 1775
	S. rubroviolaceus Bleeker, 1849
	S. schlegeli (Bleeker, 1861)
	S. spinus (Kner, 1868)
	S. tricolor Bleeker, 1847
TRICHONOTIDAE	Pteropsaron longipinnis Alllen & Erdmann, 2012
PINGUIPEDIDAE	P. clathrata Ogilby, 1911
	P. hexophthalma (Cuvier, 1829)
	P. schauinslandi (Steindachner, 1900)
TRIPTERYGIIDAE	Ceratobregma helenae Holleman, 1987
	H. cf chica
	H. sp. (pectoral base ocellus)
BLENNIIDAE	A. taeniatus Quoy & Gaimard, 1834

	Cirripectes castaneus Valenciennes, 1836
	C. quagga (Fowler & Ball, 1924)
	C. stigmaticus Strasburg and Schultz, 1953
	Crossosalarias macrospilus Smith-Vaniz and Springer, 1971
	E. fijiensis Springer, 1988 ENDEMIC
	E. pardus Springer, 1988 ENDEMIC
	Exallias brevis (Kner, 1868)
	Meiacanthus bundoon Smith-Vaniz, 1976
	Meiacanthus ovalauensis (Günther, 1880) ENDEMIC
	Plagiotremus flavus Smith-Vaniz, 1976
	P. rhinorhynchus (Bleeker, 1852)
	P. tapeinosoma (Bleeker, 1857)
	Stanulus seychellensis Smith, 1959
GOBIIDAE	Amblyeleotris arcupinna Mohlmann & Munday, 1999
	A. guttata (Fowler, 1938)
	A. randalli Hoese & Steene, 1978
	A. steinitzi (Klausewitz, 1974)
	A. yanoi Aonuma & Yoshino, 1996
	A. nocturnus (Herre, 1945)
	A. phalaena (Valenciennes, 1837)
	A. semipunctatus Rüppell, 1830
	A. striata Allen and Munday, 1996
	B. natans Larson, 1986
	B. yongei (Davis & Cohen, 1968)
	C. strigilliceps (Jordan and Seale, 1906)
	C. cf crocineus
	C. feroculus Lubbock and Polunin, 1977
	E. dorsogilva Greenfield & Randall, 2011
	E. cf flebilis
	E. karaspila Greenfield & Randall, 2010
	E. prasites Jordan and Seale, 1906
	E. punctulata Jewett and Lachner, 1983
	E. cf sigillata Jewett and Lachner, 1983
	E. sp. (banded Mark photo)
	E. teresae Greenfield & Randall, 2016
	Fusigobius duospilus Hoese and Reader, 1985
	F. inframaculatus (Randall, 1994)
	F. neophytus (Günther, 1877)
	F. signipinnis Hoese and Obika, 1988
	G. cauerensis (Bleeker, 1853)
	G. quinquestrigatus (Valenciennes, 1837)
	G. rivulatus (Rüppell, 1830)
	Grallenia sp.
	Istigobius decoratus (Herre, 1927)
	I. rigilius (Herre, 1953)
	K. rainfordi (Whitley, 1940)
	Mahidolia mystacina (Valenciennes, 1837)
	Oxyurichthys takagi Pezold & Larson, 2015
	P. semidoliatus (Valenciennes, 1837)
	P. sp. (Mark photo)
	Trimma anaima Winterbottom, 2000
	T. annosum Winterbottom, 2003
	T. anthrenum Winterbottom, 2006
	T. benjamini Winterbottom, 1996
	T. caesiura (Jordan and Seale, 1906)
	T. emeryi Winterbottom, 1984*
	T. "finistrinum" Winterbottom, 2017
	T. flavatrum Hagiwara & Winterbottom, 2007
	T. kitrinum Winterbottom & Hoese, 2015
	T. macrophthalmus (Tomiyama, 1936)
	T. maiandros Hoese, Winterbottom & Reader, 2011
	T. nasa Winterbottom, 2005
	T. okinawae (Aoyagi, 1949)

	T. preclarum Winterbottom, 2006
	T. sostra Winterbottom, 2004
	T. taylori Lobel, 1979
	T. cf xanthochrum
	V. helsdingenii (Bleeker, 1858)
	V. sexguttata (Valenciennes, 1837)
	V. strigata (Broussonet, 1782)
	Vanderhorstia sp. Allen & Erdmann, 2012
	Yongeichthys nebulosus (Forsskål, 1775)
MICRODESMIDAE	G. monostigma Smith, 1958
	G. viridescens Dawson, 1968
PTERELEOTRIDAE	Nemateleotris decora Randall and Allen, 1973
	N. helfrichi Randall and Allen, 1973
	N. magnifica Fowler, 1938
	Parioglossus nudus Rennis and Hoese, 1985
	Ptereleotris evides (Jordan and Hubbs, 1925)
	P. hanae (Jordan and Synder, 1901)
	P. heteroptera (Bleeker, 1855)
	P. microlepis Bleeker, 1856
	P.rubristigma Allen, Erdmann & Cahyani, 2012
EPHIPPIDAE	P. teira (Forsskal, 1775)
SIGANIDAE	Siganus argenteus (Quoy and Gaimard, 1824)
	S. doliatus Cuvier, 1830
	S. punctatus (Schineider, 1801)
	S. spinus (Linnaeus, 1758)
	S. uspi Gawel & Woodland, 1974 ENDEMIC
ZANCLIDAE	Zanclus cornutus Linnaeus, 1758
ACANTHURIDAE	Acanthurus albipectoralis Allen & Ayling, 1987
	Acanthurus blochi Valenciennes, 1835
	A. guttatus (Forster, 1801)
	A. lineatus (Linnaeus, 1758)
	A. nigricans (Linnaeus, 1758)
	A. nigricauada Duncker and Mohr, 1929
	A. nigrofuscus (Forsskål, 1775)
	A. nubilus (Fowler & Bean, 1929)
	A. olivaceus Bloch and Schneider, 1801
	A. pyroferus Kittlitz, 1834
	A. thompsoni (Fowler, 1923)
	A. triostegus (Linnaeus, 1758)
	A. xanthopterus Valenciennes, 1835
	Ctenochaetus binotatus Randall, 1955
	C. cyanocheilus Randall & Clements, 2001
	C. striatus (Quoy and Gaimard, 1824)
	Naso annulatus (Quoy and Gaimard, 1825)
	N. brachycentron (Valenciennes, 1835)
	N. brevirostris (Valenciennes, 1835)
	N. caesius Randall & Bell, 1992
	N. hexacanthus (Bleeker, 1855)
	N. lituratus (Bloch and Schneider, 1801)
	N. lopezi Herre, 1927
	N. minor (Smith, 1966)
	N. thynnoides (Valenciennes, 1835)
	N. tonganus (Valenciennes, 1835)
	N. unicornis Forsskål, 1775
	N. vlamingii (Valenciennes, 1835)
	Zebrasoma scopas Cuvier, 1829
	Z. veliferum Bloch, 1797
SPHYRAENIDAE	Sphyraena barracuda (Walbaum, 1792)
	S. forsteri Cuvier, 1829
SCOMBRIDAE	Grammatorcynus bilineatus (Quoy and Gaimard, 1824)
	Gymnosarda unicolor (Rüppell, 1836)
	Katsuwonus pelamis (Linnaeus, 1758)
	R. kanagurta (Cuvier, 1816)

	Scomberomorus commerson (Lacepède, 1800)
BALISTIDAE	Balistapus undulatus (Park, 1797)
	Balistoides conspicillum (Bloch and Schneider, 1801)
	B. viridescens (Bloch and Schneider, 1801)
	Canthidermis maculatus (Bloch, 1786)
	Melichthys niger (Bloch, 1786)
	M. vidua (Solander, 1844)
	Odonus niger Rüppell, 1836
	Pseudobalistes flavimarginatus (Rüppell, 1828)
	P. fuscus (Bloch and Schneider, 1801)
	Rhinecanthus aculeatus (Linnaeus, 1758)
	R. rectangulus (Bloch and Schneider, 1801)
	Sufflamen bursa (Bloch and Schneider, 1801)
	S. chrysoptera (Bloch and Schneider, 1801)
	S. fraenatus (Latreille, 1804)
	Xanthichthys auromarginatus (Bennett, 1832)
MONACANTHIDAE	Aluterus scriptus (Osbeck, 1765)
	Amanses scopas (Cuvier, 1829)
	Cantherines dumerilii (Hollard, 1854)
	Cantherines pardalis (Rüppell, 1866)
	Oxymonacanthus longirostris Bloch and Schneider, 1801
	Paraluteres prionurus (Bleeker, 1851)
	Pervagor janthinosoma (Bleeker, 1854)
OSTRACIIDAE	O. meleagris Shaw, 1796
	O. solorensis Bleeker, 1853
TETRAODONTIDAE	Arothron hispidus (Linnaeus, 1758)
	A. nigropunctatus (Bloch and Schneider, 1801)
	Canthigaster amboinensis (Bleeker, 1865)
	C. bennetti (Bleeker, 1854)
	C. epilampra (Jenkins, 1903)
	C. janthinoptera (Bleeker, 1855)
	C. ocellicincta Allen & Randall, 1977
	C. solandri (Richardson, 1844)
	C. valentini (Bleeker, 1853)
SEA CUCUMBERS	Actinopyga flammea
	Actinopyga mauritiana
	Actinopyga miliaris
	Bohadschia argus
	Bohadschia similis
	Holothuria atra
	Holothuria edulis
	Holothuria fuscogilva
	Holothuria leucospilota
	Holothuria whitmaei
	Pearsonothuria graeffei
	Stichopus chloronotus
	Stichopus horrens
	Thelenota ananas
	Thelenota anax



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