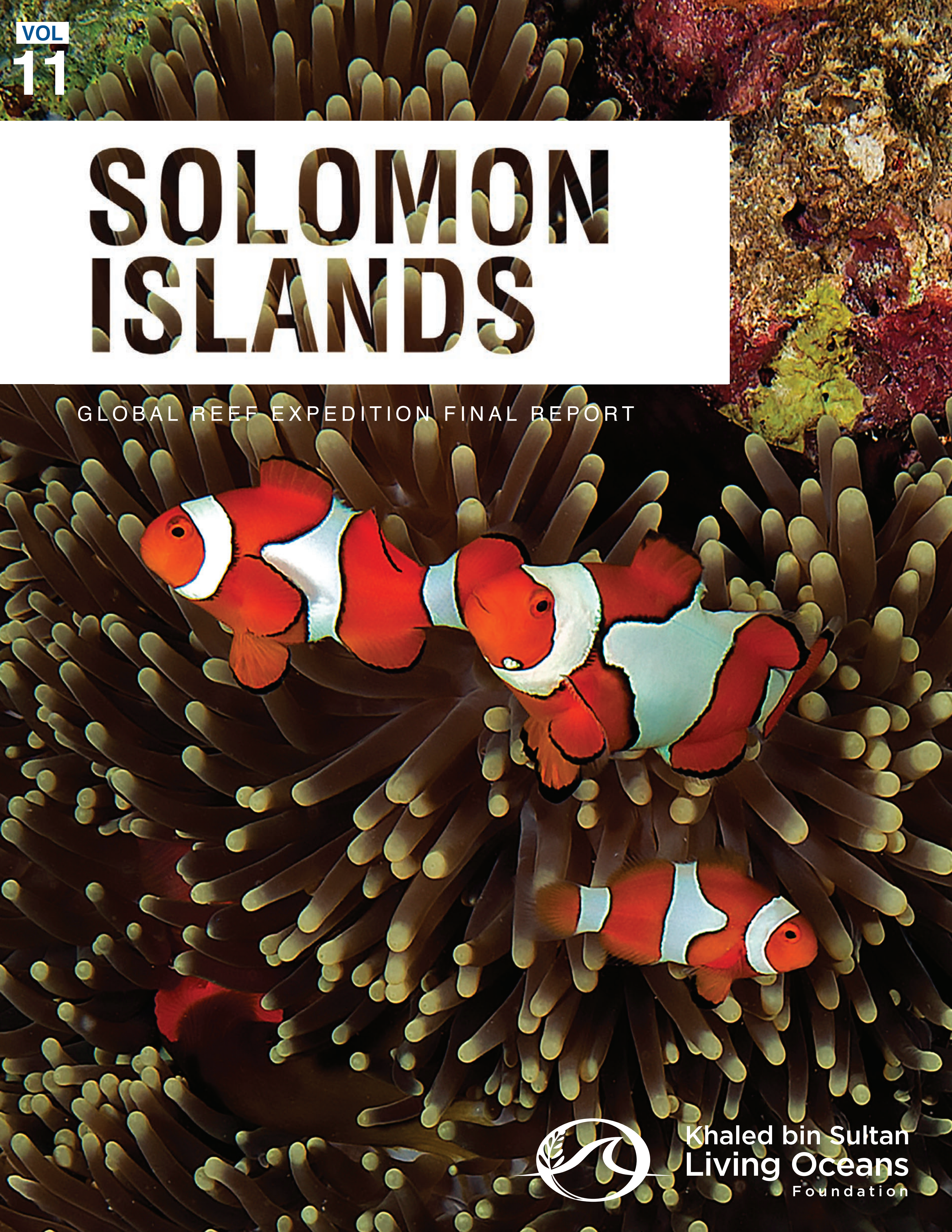
VOL 11

SOLOMON ISLANDS

GLOBAL REEF EXPEDITION FINAL REPORT



Khaled bin Sultan Living Oceans Foundation

VOL
11

SOLOMON ISLANDS

GLOBAL REEF EXPEDITION FINAL REPORT

Khaled bin Sultan Living Oceans Foundation

Renée D. Carlton, Alexandra C. Dempsey, Katie Lubarsky,
Ivory Akao, Mohammed Faisal, and Samuel Purkis

Khaled bin Sultan Living Oceans Foundation

Science Without Borders®

The findings presented in this report were collected as part of the Global Reef Expedition through the support provided by His Royal Highness Prince Khaled bin Sultan.

All research was completed under an MOU between the Ministry of Fisheries and Marine Resources and KSLOF (MFMR Ref F/12/11 issued 20 August 2014) and under Research Permit Number RP/2014/006 issued by the Ministry of Environment, Climate Change, Disaster Management and Meteorology on 21 August 2014. Further permissions were acquired from the Provincial Governments in Temotu Province, Isabel Province and Western Province. This report was developed as one component of the Global Reef Expedition: Solomon Islands research project.

The Khaled bin Sultan Living Oceans Foundation (KSLOF) is a nonprofit organization dedicated to providing science-based solutions to protect and restore ocean health. KSLOF was incorporated in California as a 501(c)(3), public benefit, Private Operating Foundation in September 2000. Since then, the Living Oceans Foundation has worked to conserve the world's oceans through research, outreach, and education.
www.livingoceansfoundation.org

Khaled bin Sultan Living Oceans Foundation
7 Old Solomons Island Road, Suite 200
Annapolis, MD 21401
info@lof.org

Chief Scientist: Dr. Samuel Purkis
Director of Science Management: Alexandra C. Dempsey
Marine Ecologist: Renée D. Carlton

Photo Credits:
Cover: Ken Marks
Pg. 4, 10, 18, 21, 31, 38, 44, 47, and 49 by Ken Marks
Pg. 22 by João Monteiro

Citation: Global Reef Expedition: Solomon Islands. Final Report. Carlton, R., Dempsey, A., Lubarsky, K., Akao, I., Faisal, M., and Purkis, S. (2020) Khaled bin Sultan Living Oceans Foundation, Annapolis, MD. Vol 11.

ISBN: 978-0-9975451-6-6

TABLE OF CONTENTS

EXECUTIVE SUMMARY

On the Global Reef Expedition—one of the largest coral reef studies in history—the Khaled bin Sultan Living Oceans Foundation conducted research in the Solomon Islands to map and characterize shallow marine habitats and assess the status of coral reef benthic and fish communities. Working in partnership with local officials and scientists from around the world, the Foundation surveyed reefs in the Western, Isabel, and Temotu Provinces from October 26 through November 24, 2014. The Global Reef Expedition: Solomon Islands Final Report *summarizes the Foundation's findings from this research mission and provides recommendations that can help preserve these coral reefs for generations to come.*

The Khaled bin Sultan Living Oceans Foundation (KSLOF) was established by His Royal Highness Prince Khaled bin Sultan with a mission to study and provide valuable knowledge to better preserve coral reefs around the world. To do this, KSLOF embarked on the Global Reef Expedition (GRE) with the goal of surveying coral reefs and their benthic and fish communities on a global scale. With the help of local experts and a team of international scientists, KSLOF was able to use standardized methodology to collect the most comprehensive global coral reef data to date.

During the GRE, collecting data in the Coral Triangle was important to the Foundation as this region of the world boasts some of the highest tropical marine diversity and up to 76% of the world's marine species.

> This report provides an assessment of **coral reefs** and **reef fish** in the **Solomon Islands** along with **conservation recommendations.**

The Solomon Islands are found at the eastern edge of the Coral Triangle, making it a valuable country to include on the GRE. In October-November 2014, KSLOF visited the Western, Isabel, and Temotu Provinces of the Solomon Islands with the objectives:

1. **Map and characterize the shallow marine habitats; and**
2. **Conduct assessments and research to understand the current status of Solomon Islands coral and fish communities.**

On the mission to the Solomon Islands, the Foundation brought together a team of scientists, working closely local officials to conduct 473 benthic surveys and 632 fish surveys at 68 dive sites among the three provinces. What was found was surprising. There was high variability in both the benthic and fish communities found among the survey sites, but overall, what was most alarming was the seemingly overfished nearshore fish communities.

HABITAT MAPPING

In total, KSLOF mapped and characterized over 3,000 square km of the Western, Isabel, and Temotu Provinces. A wide variety of marine habitats that are important to the diversity and conditions of the reef were mapped, including mangroves, seagrasses, and multiple reef habitats both inside and outside of the lagoons. These are high-resolution maps with a resolution of 2 m x 2 m. These maps are all available to view on our website at www.lof.org/maps and will be valuable to marine spatial planning efforts in these areas. We encourage the public, scientists, and policymakers to consult with these maps, particularly those interested in marine management, to better understand the areas that might require protection.

BENTHIC COVER ASSESSMENTS

The benthic habitats of the Solomon Islands were generally in moderate condition with notable variability among the Provinces. In the Western Province, sites surveyed near Marovo had the highest live coral cover, while areas with the lowest live coral were found near Munda. The substrate that was unoccupied by coral was instead dominated by crustose coralline algae (CCA) which indicates the invertebrate and fish communities near Munda may be regulating macroalgal growth. Gizo also had a notably low live coral cover with the reefs being dominated by turf algae and CCA. Nono Lagoon had slightly better live coral cover, though still not as high as would be expected.

Isabel Province has the most protections in place because of the designated Arnavon Conservation Area. KSLOF surveyed both within the conservation area around Sikopo and Kerehikapa and outside near Malakobi. The reefs of Kerehikapa had an average of 51% live coral cover which was some of the best we observed in the Solomon Islands. However, Sikopo had only 30% live coral which may be attributed to damage sustained during the tsunami that hit the region in 2007. Malakobi had similar live coral cover as Sikopo and may have sustained similar damage during the tsunami, however, continued monitoring is recommended.

Temotu Province was the most remote region surveyed in the Solomon Islands. Within this Province, the Reef Islands had the lowest live coral cover, measuring 31%. Interestingly, there were many large patches of *Halimeda spp.*, an erect coralline algae, observed in this area, particularly in depths deeper than 10 m. There was also higher live coral cover observed at depths greater than 10 m, measuring an average of 51%. Vanikoro and Utupua are small atolls found within the Temotu Province and had relatively high average live coral cover, measuring 42% and 44% respectively. These were some of the highest percentages of live coral found within the Province and in nearly all of the stations surveyed.

FISH COMMUNITY ASSESSMENT

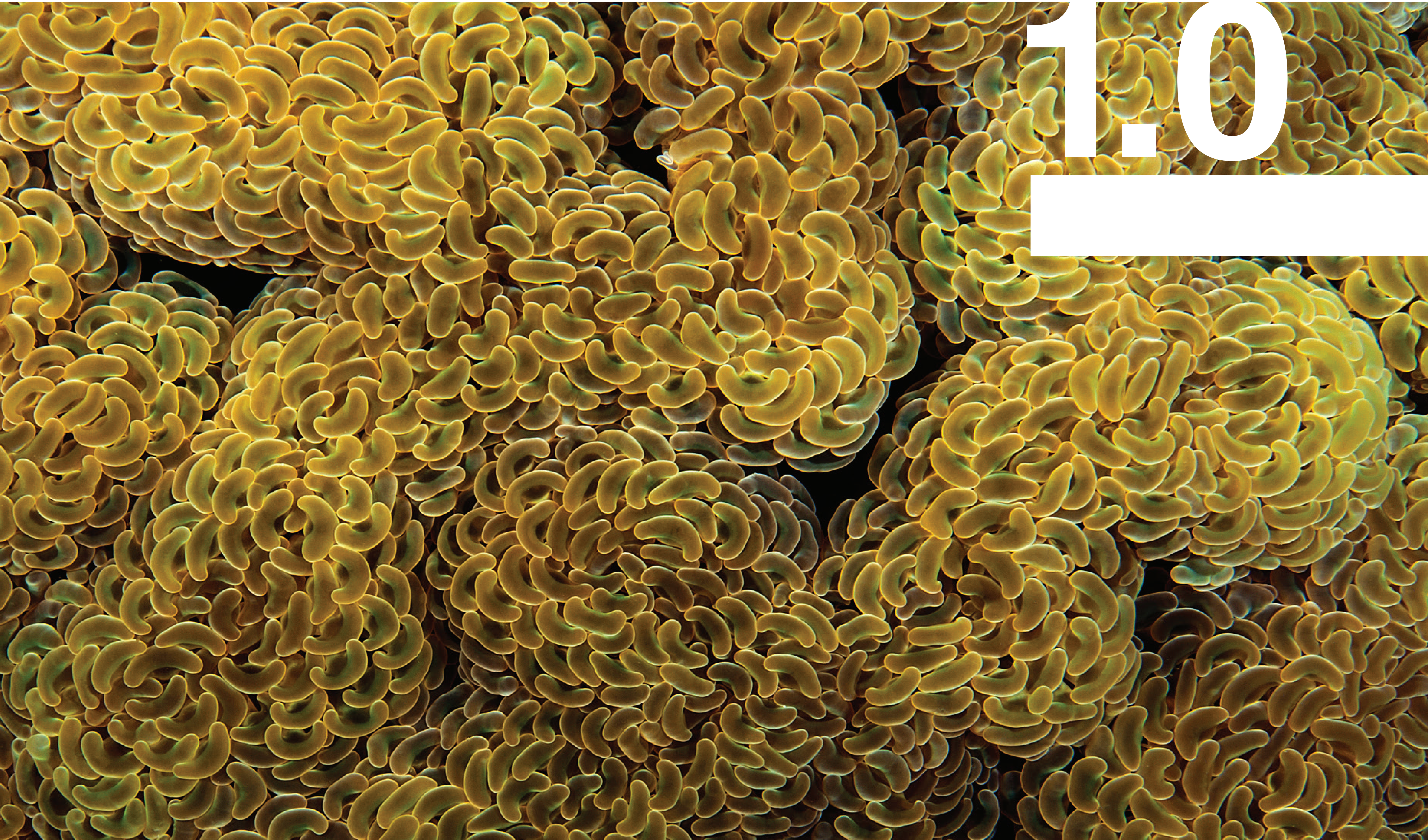
The fish communities in the Solomon Islands showed distinct patterns across sites that likely reflected patterns in fishing pressure across the archipelago. The fish communities in the Temotu Province, where fishing pressure is likely much less, were more diverse, had the highest fish species richness, density, and biomass. More populated areas, such as around Gizo, had much smaller fish in lower trophic levels, indicating over-exploitation of nearshore fisheries. Overall, even with relatively higher metrics being observed in the Temotu Province, the fish communities were in dire shape, having some of the worse metrics seen on the Global Reef Expedition, especially when compared to nearby South Pacific nations.

CONSERVATION RECOMMENDATIONS

The Solomon Islands are a treasure to the world, with some of the most unique coral and fish assemblages. Unfortunately, it appears these habitats are in need of aggressive conservation efforts. Conservation of the fish communities should be a priority for the communities that rely on them for sustenance. Regulating catch size and number will help improve the overall biomass and abundance in all trophic levels, as they are currently being dominated by few, small fish.

While in the Solomon Islands, KSLOF scientists observed evidence of elevated numbers of Crown-of-Thorns Starfish (COTS), a poisonous corallivore. When an outbreak occurs, COTS can have detrimental effects on the reef system. In other regions of the world, KSLOF has observed, first-hand, the destruction COTS can have on a reef where it can essentially consume and kill every coral on a reef system. It is important to educate communities on the damage these organisms can cause and develop a management plan should an outbreak occur.

1.0



INTRODUCTION

1.0

The Solomon Islands are made up of numerous archipelagos comprised of uplifted reefal limestone and volcanic islands found within the eastern edge of the Coral Triangle **(Figure 1)**. The Coral Triangle boasts some of the highest tropical marine diversity and up to 76% of the world's marine species[1,2]. With coral reefs surrounding the nearly 1,000 islands and cays[3], the Solomon Islands were of interest to the Khaled Bin Sultan Living Oceans Foundation (KSLOF). Despite the high marine biodiversity found here, the reefs of the Solomon Islands are relatively understudied[2]. Travel among the many islands is both difficult and unreliable, hindering the ability of scientists to reach some of the more remote locations. The donated time of the M/Y *Golden Shadow* allowed a team of international scientists to map and survey marine habitats within three provinces of the Solomon Islands: the Western, Isabel, and Temotu Provinces.

The Khaled bin Sultan Living Oceans Foundation began the Global Reef Expedition (GRE) with the goal of better understanding the status of coral reefs globally and to contribute to conservation efforts of this fragile ecosystem. KSLOF visited the Western, Isabel, and Temotu provinces in October-November 2014 to undertake the objectives which were common to all GRE sites:

1. Map and characterize the shallow marine habitats; and
2. Conduct assessments and research to understand the current status of Solomon Islands coral and fish communities.

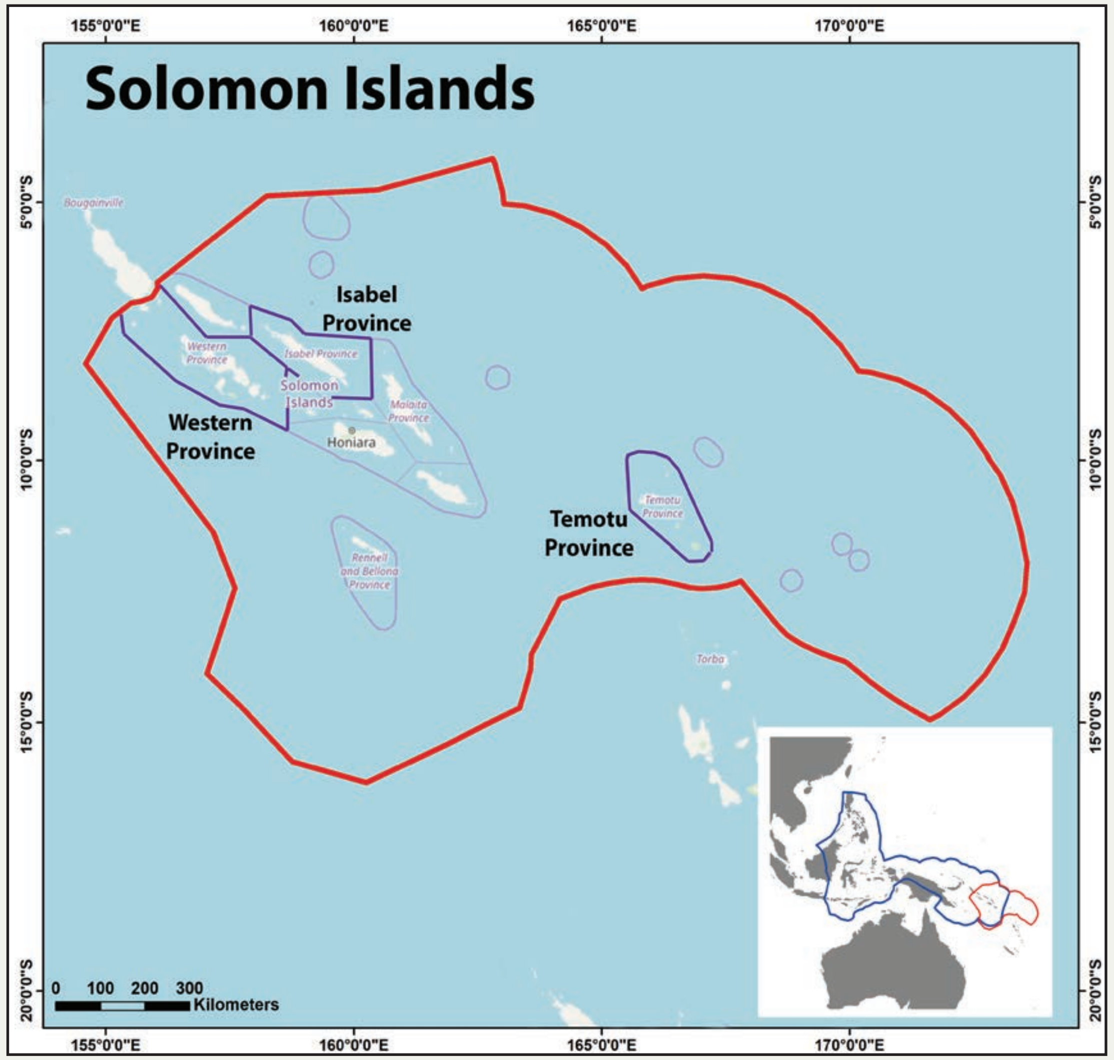
The data collected on the research mission in the Solomon Islands provides important baseline information about the reefs' benthic and fish communities. The marine habitats of the Solomon Islands are invaluable, particularly to the local inhabitants that rely on them for daily sustenance. In a study completed by CGIAR in 2012, coral reefs of the Solomon Islands provide an average of $18,000 to $75,000 SBD (Solomon Island Dollar) per respondent per year in direct use-value[4]. Of this, food from sustenance fishing was the greatest economic contributor with fish accounting for 23-39% of the total direct-use value in non-coral trading communities[4]. Some communities collect, trade, and sell coral and reef organisms as a form of income generation, which, unregulated, can have negative effects on the reef ecosystem.

Besides the highly valuable coral reefs, the Solomon Islands are rich in forests, metals and minerals such as gold, bauxite, and nickel, which are being exported by multinational mining companies[5]. Unfortunately, extraction of these resources have had detrimental effects on the reefs through excessive sedimentation, nutrient runoff, and most recently an expansive oil spill due to the grounding of a cargo ship carrying mined bauxite[6]. Natural forest logging also creates excessive sedimentation through the destabilization of hillsides and the removal of vast areas of tropical rainforests. In a study by Albert et al. (2014), a recent effort to minimize the impacts of deforestation led by the communities around Marovo Lagoon have had a positive impact on the benthic and fish communities. Through the cessation of logging and modification of catchment practices, the communities reduced the overall runoff from nearby logging resulting in more positive reef conditions[7].

Marine resource management in the Solomon Islands is primarily led by local villages who have tenure over nearshore reef access and customary entitlement to marine territories is managed through means of various cultural practices[8]. Simply stated, access to reefs and offshore waters is managed by the chiefs of territories adjacent to the area and shared marine resources are agreed upon by the local communities[9]. Traditionally, most inshore fisheries used the practice of foraging which was a relatively sustainable method of fishing and primarily opportunistic[10]. Traditional forage fishing does not exclusively exploit one area of the reef; rather, the fishers travel to different parts of the reef depending on the fishing success. This allows for fishing pressure to be more evenly distributed and for more successful recovery of the fish communities than can be achieved using non-foraging strategies. However, with the introduction of better technology, the use of more destructive fishing methods, and an increase in both artisanal and commercial fisheries, the inshore fish stocks are at risk of depletion[8].

> The data collected on this research mission provides **important information** about **benthic** and **fish** communities on **coral reefs** in the **Solomon Islands.**

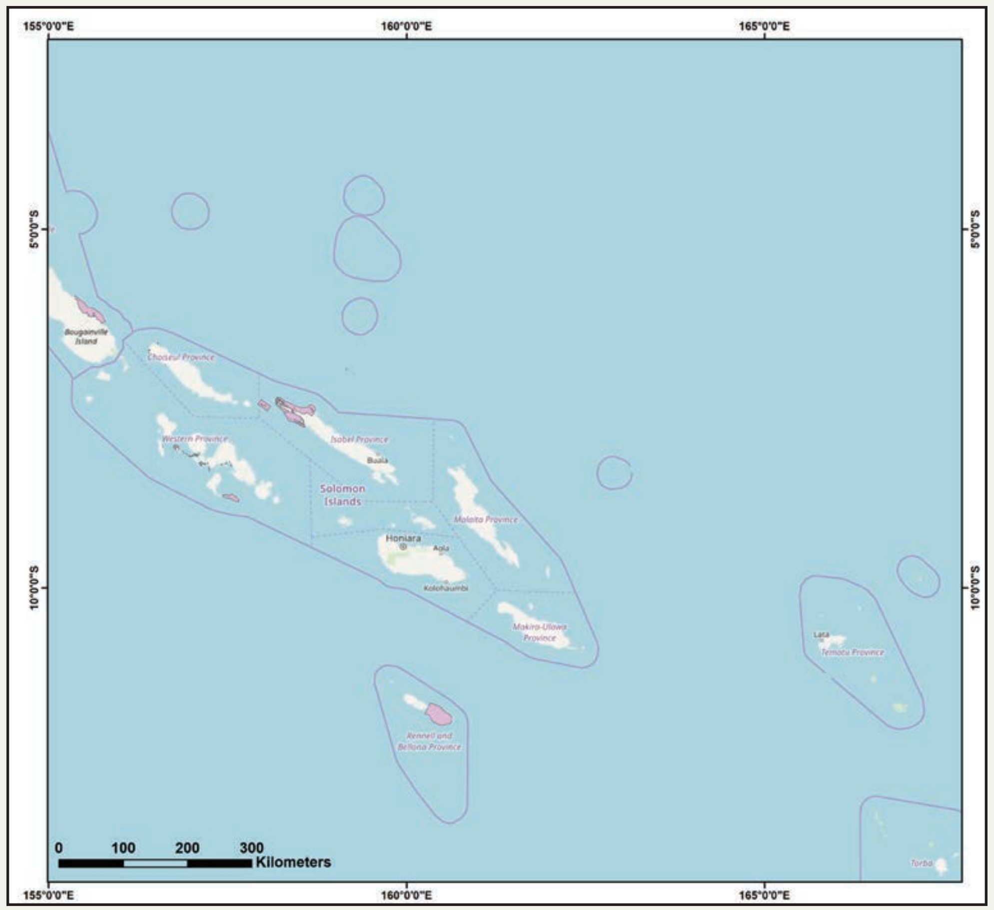
Figure 1 MAP OF THE SOLOMON ISLANDS EXCLUSIVE ECONOMIC ZONE OUTLINED IN RED, WITH THE PROVINCES SURVEYED OUTLINED IN PURPLE. THE INSET MAP SHOWS THE ESTIMATED OUTLINE OF THE CORAL TRIANGLE (BLUE LINE) AS DEFINED BY THE CORAL TRIANGLE ATLAS.



SOLOMON ISLANDS EEZ · PROVINCE OUTLINE · CORAL TRIANGLE

INTRODUCTION

Figure 2 CURRENT MARINE PROTECTED AREA (MPA) DESIGNATIONS IN THE SOLOMON ISLANDS ARE HIGHLIGHTED IN PINK. THESE AREAS ARE INTERNATIONALLY RECOGNIZED, LOCALLY MANAGED, AND HAVE VARYING MANAGEMENT REGULATIONS SPECIFIC TO EACH AREA.



MPAS

Since the 1990s, private organizations, public agencies, and NGOs have worked together to establish locally managed conservation areas in the Solomon Islands to protect nearshore marine habitats from destruction (Figure 2). One of the largest and only formally recognized Marine Protected Area (MPA) in the Solomon Islands is the Arnavon Marine Conservation Area in the Arnavon Islands, north of Santa Isabel. This conservation area was established to protect the important hawksbill sea turtle rookery and has benefited the coral ecosystem within the area[11]. In this conservation area, the local communities and government have banned: all mining; harvesting of commercially important species such as all species of turtles, pearl shell, trochus, sea cucumbers, giant clams, green snails, sharks, corals, pigeons, and milkfish; logging or removal of vegetation is prohibited except for sustenance; line fishing for reef fish except for sustenance; hunting of megapode birds except for seasonal harvesting of their eggs; and commercial collection of all other marine or terrestrial organisms except for sustenance[12].

Another network of marine conservation areas has been established around Gizo Island in the Western Province through the development of the Gizo Environmental Livelihood and Conservation Association (GELCA), a consortium of local representatives from villages around the Gizo islands. GELCA has established both permanent marine protected areas (no-take) and multiple-use marine protected areas (MPAs) called the GELCA Conservation Protection Area. The conservation area includes 10 management areas where conservation rules have been established. In November 2011, the GELCA released the GELCA Resource Management Plan which outlines the regulations, locations, and enforcement plan for the GELCA MPAs[13].

Throughout the Solomon Islands, 90 internationally recognized marine conservation areas have been designated at the time of this publication. Despite these conservation efforts, the marine resources of the Solomon Islands still require attention. Most of the MPAs in the Solomon Islands are small, in total accounting for only 0.12% of the total EEZ[14]. KSLOF visited some locations near and away from a select few of these conserved areas to get a comprehensive understanding of the benthic (reef bottom, including coral, algae, and sessile invertebrates) and reef fish communities. Of the sites visited near conservation areas, KSLOF particularly focused on areas where commercial mining and logging have not been allowed (as of the time of our visit in 2014), particularly at sites in the Temotu province, south of the more populated provinces to the north. It is the goal of KSLOF to provide valuable baseline information about the status of the coral reefs in the Solomon Islands, and that through this report, effective protection and management can be expanded on a large scale.

> The goal of the Khaled bin Sultan Living Oceans Foundation is to provide valuable baseline information about the **status of coral reefs in the Solomon Islands.**

2.0 METHODS

2.1 SITE DESCRIPTIONS

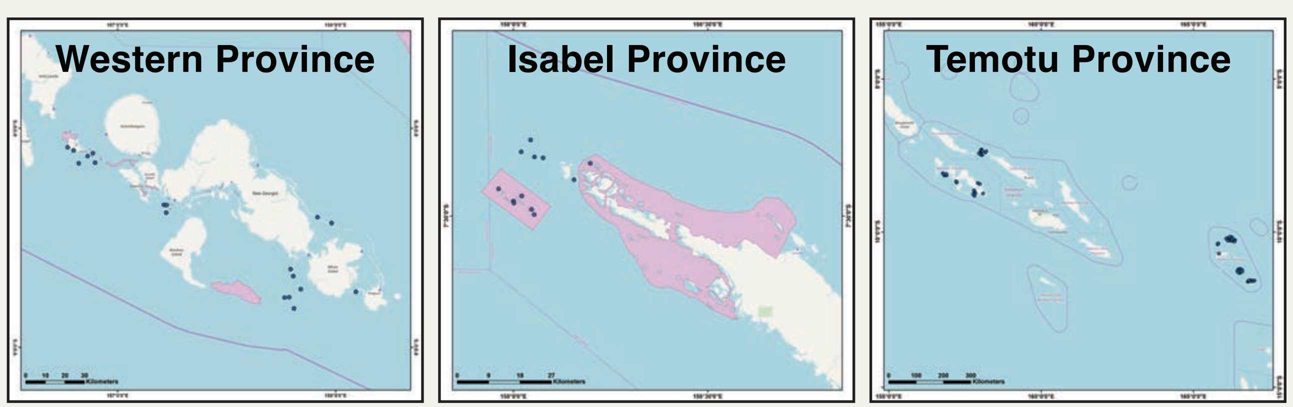
The GRE mapped and surveyed coral reefs in three provinces of the Solomon Islands: Western, Isabel, and Temotu. A total of 68 dive sites (Figure 3) were surveyed, among which 473 benthic habitat transects and 615 fish surveys were completed.

The dive sites were selected based on accessibility by boat and with the goal of including all reef habitats (as defined from the satellite images, Figure 5a). Table 1 shows the total number of surveys conducted at each location. The extensive surveys were selected to include remote, uninhabited locations that, at the time of sampling, had not previously been studied to this extent, as well as locations within and near already designated protected sites. The M/Y *Golden Shadow* and its support vessels were graciously donated for use on this expedition to allow KSLOF and invited researchers to easily gather data in some of the most understudied regions of the Solomon Islands.

Table 1 TOTAL NUMBER OF DIVE SITES AND TRANSECTS COMPLETED AT EACH LOCATION IN 2014.

PROVINCE	LOCATION	NUMBER OF DIVE SITES	NUMBER OF BENTHIC TRANSECTS	NUMBER OF FISH TRANSECTS
WESTERN	GIZO	6	78	72
	MAROVO	2	8	19
	MUNDA	3	43	32
	NONO	7	37	67
ISABEL	KEREHIKAPA	3	19	21
	MALAKOBI	6	38	52
	SIKOPO	3	20	33
TEMOTU	REEF ISLANDS	15	108	122
	TINAKULA	3	12	25
	UTUPUA	11	61	96
	VANIKORO	9	49	93

Figure 3 FISH AND BENTHIC SURVEY SITE LOCATIONS IN WESTERN, ISABEL, AND TEMOTU PROVINCES. BLUE DOTS ARE SURVEY SITE LOCATIONS AND MARINE PROTECTED AREAS FOR THE PROVINCES SURVEYED ARE FILLED IN WITH PINK.

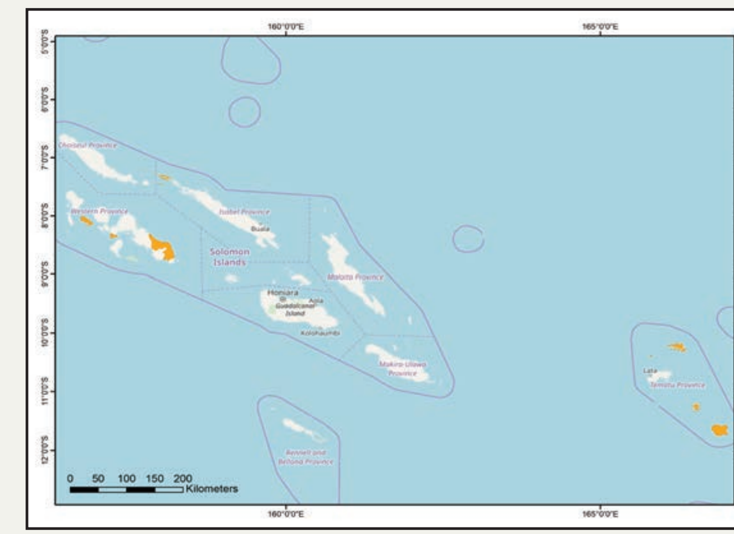


SURVEY SITES   MARINE PROTECTED AREAS

2.2 HABITAT MAPPING

Using multispectral WorldView-2 satellite imagery (DigitalGlobe Inc., Washington D.C., USA) in combination with data obtained from aerial surveys and ground-truthing (Figure 4) by KSLOF fellows and researchers, high-resolution bathymetric maps and thematic habitat maps were created for shallow marine environments found within the lagoons and forereefs (see examples of map outputs in Figures 5a-c)[15]. The remote sensing data and their derivatives will be useful not only for marine spatial planning but also as a reference for future research on the Solomon Islands' coral reefs. The generated maps extend from the shoreline to approximately 25 m water depth. Ground-truthing, which was used to define habitat classes, and guide interpretation of the remote sensing data (Figure 4), included continuous acquisition of depth soundings, drop-camera deployment, samples of sediment and hard substrates, snorkel and dive assessments, and fine-scale photo-transect surveys.

Figure 4 AREAS HIGHLIGHTED IN YELLOW ARE AREAS MAPPED BY KSLOF. ALL MAPS CAN BE FOUND ON OUR MAP PORTAL AT WWW.LOF.ORG/MAPS.



AREAS MAPPED

Figure 5a THESE THREE EXAMPLE MAP OUTPUTS ARE OF GIZO, SOLOMON ISLANDS. EXAMPLE OF (A) A TRUE-COLOR SATELLITE IMAGE CAPTURED FROM THE WORLDVIEW-2 SENSOR, (B) A HABITAT MAP, AND (C) A SPECTRALLY-DERIVED BATHYMETRY MODEL. | SATELLITE IMAGE

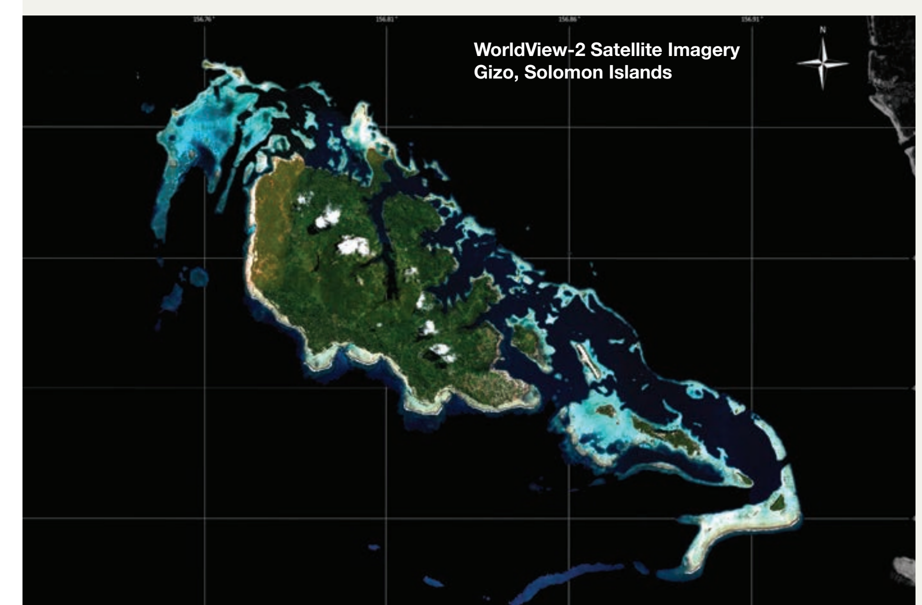


Figure 5b HABITAT MAP WITH CLASSIFICATIONS

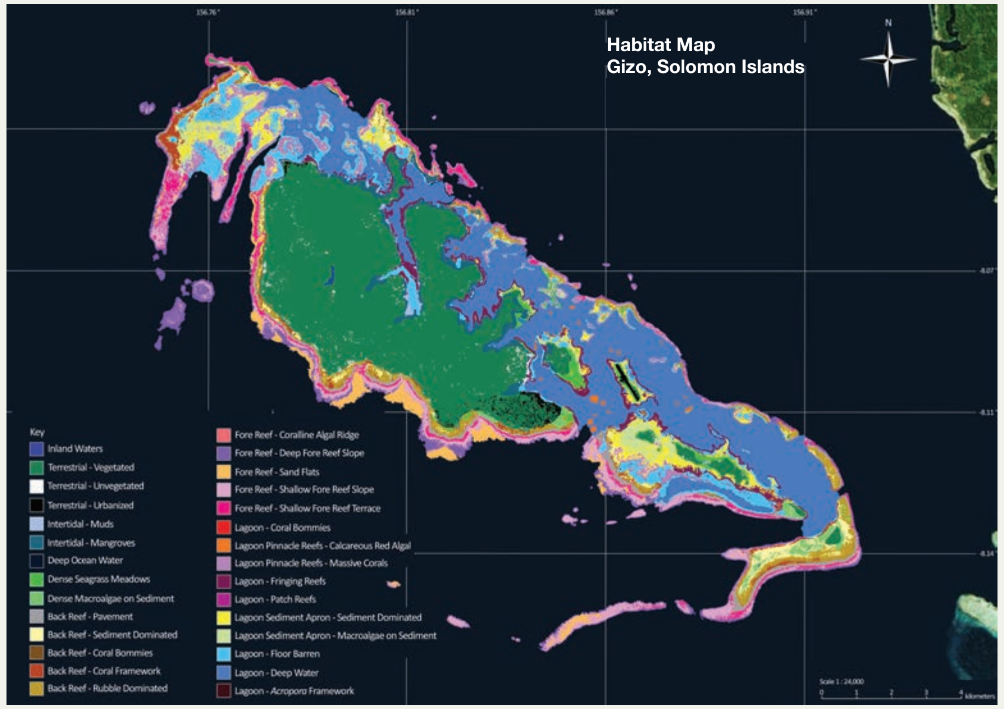
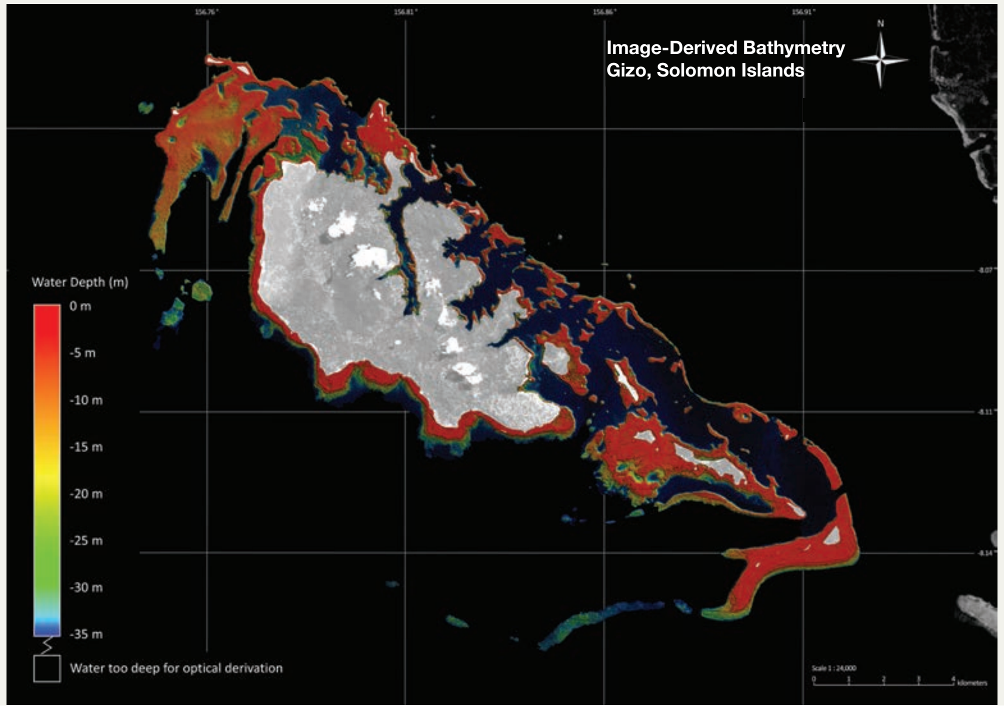


Figure 5c BATHYMETRY MAP WITH DEPTHS



2.2 a SATELLITE IMAGERY

A total of 2,662 sq. km of DigitalGlobe Inc. WorldView-2 (8 band) satellite imagery was purchased by KSLOF for the regions mapped. The satellite images had a spatial resolution of 2×2 m (each pixel covers a 4 m^2 area) enabling real-time navigation in the field to locate features of interest. KSLOF Fellows from Nova Southeastern University and the University of Miami used the scenes in conjunction with a differential GPS device to navigate throughout the atolls. Modelers used the imagery, combined with the ground-truthing data, to create bathymetric and benthic habitat maps[15].

2.2 b BENTHIC VIDEO

An underwater tethered digital video camera, commonly termed a “drop-cam,” was used to gather video of the benthic composition at each drop-cam location (Figure 6). At each station, the drop-cam was lowered from the survey boat to within 0.5 m of the seafloor and video recorded for up to 60 seconds. During this time, a laptop operator watched the video in real-time and guided the drop-cam operator to raise or lower the camera to avoid any topography. In this manner, any damage to marine life was prevented. The video was recorded on a ruggedized laptop with geo-position, time, date, boat heading, and boat speed digitally etched into the video stream. Drop-cam deployment was limited to depths shallower than 40 m due to the 50 m length of the tether cable.

Figure 6 SEAVIEWER UNDERWATER VIDEO “DROP-CAM” USED TO RECORD BENTHIC COMPOSITION AROUND EACH ISLAND.

2.2 c HABITAT CLASSIFICATIONS

Habitat classifications of all the marine and terrestrial habitat types were determined using the satellite imagery and ground-truthing using benthic video surveys. The combination of all data collected was used for the development of a habitat classification scheme and training of *eCognition* software to develop object-based classification models[15]. A total of 31 habitat types were defined for all the studied sites **(Table 2)**. When calculating and presenting total area coverage of the different habitat classifications, multiple habitat types were sometimes combined **(Table 2)**. For example, for back-reef coral habitats, we combined back-reef coral bommies and back-reef coral framework to represent this broad reef environment.

2.2 d ACOUSTIC WATER DEPTH SOUNDINGS

Sonar soundings were gathered by KSLOF fellows along transects using a *Syqwest Inc. Hydrobox,* a single-beam acoustic transducer operating at 50 Hz **(Figure 7)**. Each sounding was positioned using differential GPS and the data were recorded on a ruggedized laptop. The soundings were used to train a satellite water-depth derivation model, which is based on the spectral attenuation of light in the water column[16]. The final topo-bathymetric maps have the same spatial resolution as the satellite imagery from which they were extracted (i.e. 2 × 2 m).

Figure 7 ACOUSTIC SONARS USED IN THE SURVEYS. SUB-SEABED PROFILER (LEFT) AND SINGLE-BEAM SONAR (RIGHT).

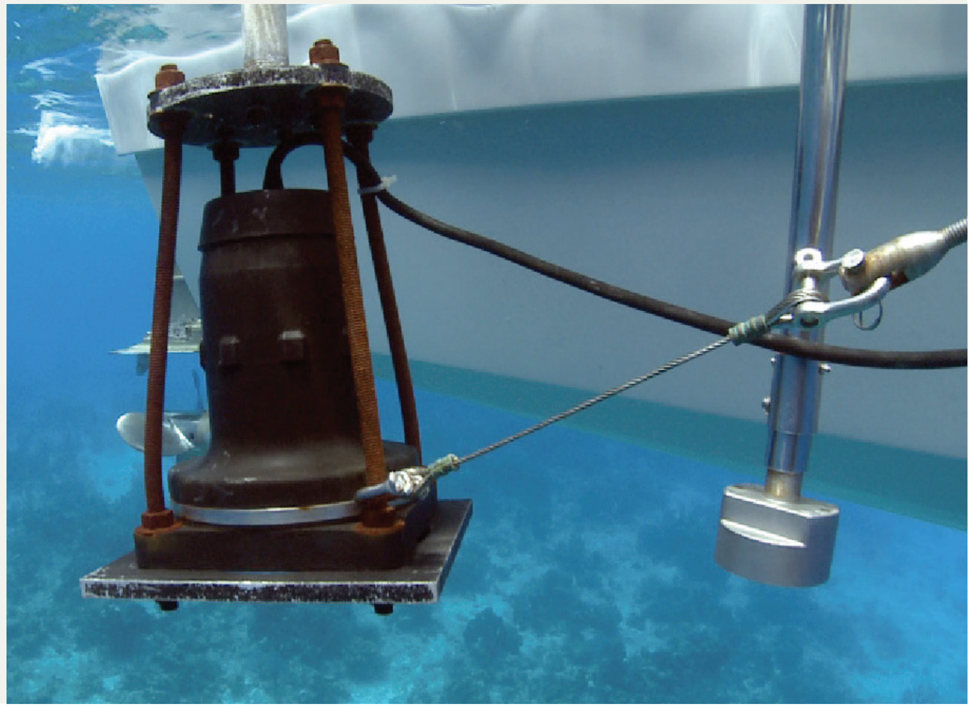


Table 2 CLASSES OF BENTHIC HABITAT USED FOR MAPPING AND AREA CALCULATIONS. THE MEASUREMENT OF EACH AREA IS PRESENTED IN TABLE 3 FOR EACH OF THE LOCATIONS SURVEYED. KSLOF COMBINED SOME HABITATS (RIGHT COLUMN) UNDER A BROADER CLASSIFICATION (LEFT COLUMN) FOR THE PURPOSES OF THIS REPORT.

HABITAT CLASSIFICATIONS	
Back reef coral	Back reef coral bommies
	Back reef coral framework
Deep forereef slope	
Deep lagoonal water	
Lagoonal coral	Lagoonal Acropora framework
	Lagoonal floor — coral bommies
	Lagoonal fringing reefs
	Lagoonal patch reefs
	Lagoonal pinnacle reefs — branching coral dominated
	Lagoonal pinnacle reefs — massive coral dominated
Lagoonal substrate	Back reef — pavement
	Back reef — rubble dominated
	Back reef — sediment dominated
	Lagoonal floor — barren
	Lagoonal sediment apron — sediment dominated
Lagoonal macroalgae dominated substrate	Lagoonal floor — macroalgae on sediment
	Lagoonal pinnacle reefs — calcareous red-algal conglomerate
	Lagoonal sediment apron — macroalgae on sediment
Nearshore algal communities	Coralline algal ridge (reef crest)
Dense macroalgae on sediment	
Shallow forereef community	Reef crest
	Shallow forereef slope
	Shallow forereef terrace
Forereef sand flats	
Dense seagrass meadows	
Mud flats	
Reef top algal mats	
Terrestrial	Beach sand
	Terrestrial vegetation
	Unvegetated terrestrial
Mangroves	
Inland waters	
Urban	

2.3 CORAL REEF COMMUNITY SURVEYS

Living Oceans Foundation scientists and fellows on the GRE used a combination of quantitative methods, including belt transects, point intercept transects, and quadrats to assess benthic and fish communities of reefs located in the Solomon Islands. This standardized collection methodology provides robust data that can be compared regionally and globally. This report provides a broad discussion of trends and patterns as a prelude to more in-depth analysis.

2.3 a BENTHIC COVER ASSESSMENTS

Cover of major functional groups and substrate type (Box 1) was assessed along 10 m transects using recorded observations and/or photographic assessments. The major functional groups included: corals identified to genus, other sessile invertebrates such as leather corals, anemones, and others identified to phylum or class, and six functional groups of algae. At least two KSLOF surveyors used SCUBA-recorded observations to record what was observed on the benthos using a point intercept method. This technique required the surveyor to lay out a 10 m transect line and record the organism and substrate type at every 10 cm mark (total 100 points per transect). A minimum of four transects among the five depth strata were completed at each dive site (Figure 8), and when possible, surveys were completed at 25, 20, 15, 10, and 5 m water depths.

At some locations, we conducted a photographic assessment to supplement the point-intercept surveys. On occasion, we were not able to complete these surveys at every depth due to SCUBA time limitations, so we supplemented this dataset with photographic assessments. In this sampling technique, a scientific diver used a 1 m × 1 m quadrat, flipping it over a total of 10 times per transect to photograph a full 1 × 10 m photo transect (Figure 9) at each depth. As before, when possible, the diver completed at least one survey at 20, 15, 10, and 5 m depth at each site. In order to measure the benthic community, the digital photographs were downloaded and analyzed using *Coral Point Count with Excel Extensions* (CPCe), a software developed by Nova Southeastern University's National Coral Reef Institute (NCRI)[17]. The 1 × 1 m images were imported into the software where 50 random points were overlaid on each photograph. A KSLOF scientist then defined the organism and substrate type directly underneath the point (Figure 10). These data were then exported into a Microsoft Excel (2013) spreadsheet and added to the benthic survey database for further analysis.

Figure 8 A DIVER CONDUCTING A BENTHIC SURVEY. DIVER USES A 10 M TRANSECT LINE AND RECORDS BENTHIC SUBSTRATE TYPE AND COVER EVERY 10 CM. PHOTO BY KEN MARKS.

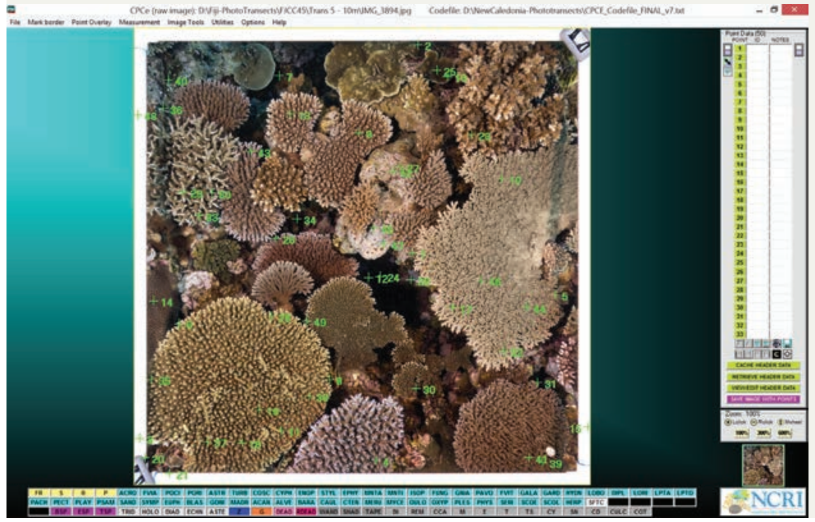
The benthic substrate cover percentages were calculated for each island as the average percentage of all transects collected at that island, binned first by depth, then by site. The percentage of each substrate type was calculated by dividing the total number of samples observed in each depth on each transect by the total number of points recorded, multiplied by 100. The average percentage of all transects at each location is presented as the measure of each substrate type.

Box 1 CLASSIFICATION OF SUBSTRATE TYPES RECORDED DURING BENTHIC TRANSECT SCUBA SURVEYS.

BENTHIC HABITAT
SUBSTRATE TYPE
Live Coral
Dead Coral
Fused Rubble
Pavement
Rubble
Sand/Sediment
Recently Dead Coral
LIVE COVER
Algae
Macroalgae
Crustose Coralline Algae (CCA)
Erect Coralline Algae
Turf Sediment
Turf
Cyanobacteria
Other Invertebrates
Coral (to Genus)

Figure 9 A DIVER TAKES A PHOTO OF A 1 M × 1 M SQUARE QUADRAT. TEN PHOTOS FOR EACH TRANSECT ARE COMPLETED AT DIFFERENT DEPTHS. BENTHIC DATA IS ALSO COLLECTED USING TRANSECT LINES AS SHOWN IN FIGURE 8.

Figure 10 EXAMPLE OF A PHOTOGRAPHED QUADRAT IMPORTED INTO CPCE SOFTWARE, WITH RANDOMLY PLACED POINTS FOR IDENTIFICATION. FIFTY RANDOM POINTS ARE OVERLAID ON EACH PHOTO QUADRAT, AND SUBSTRATE TYPE AND LIVE COVER CLASSIFICATION ARE IDENTIFIED FOR EACH POINT.



To further analyze the coral and algal cover, the sum of the specific algae types or coral genus recorded on each transect was divided by the total number of algae or coral observed per transect. The average of the percentages for each algae type is presented in (Figure 13).

To measure overall coral diversity by genus, we used the Simpson Index of Diversity which is commonly used to characterize species diversity in a community[18]. This index uses the total number of individual coral colonies of a specific genus observed per island, and the total number of genera, to provide a number to represent the total diversity of the island community. Using this index, the diversity will fall within a range of 0-1 with 0 being low diversity, and 1 being the most diverse.

This standardized collection methodology **provides robust data** that can be compared **regionally and globally.**

2.3 b FISH ASSESSMENTS

Reef fish surveys were conducted by KSLOF Scientists and Fellows at selected locations. The survey transects covered depths between 1 to 22 m, but most of the surveys were between 5 and 20 m depth (Figure 11). Transects were deployed at deep (>12m) and shallow (<10m) sections of the reefs, as allowed by the morphology of the dive site. At least two deep and two shallow transects were conducted by divers. The fish assemblages at each dive site were surveyed following a fish visual census technique modified from the survey principles described by English et al. (1994)[19]. The diver identified and counted fish along a 30 × 4 m transect over a period of 10 to 15 minutes.

Fish assemblages were characterized in terms of species richness, abundance, and standing stock biomass. Fish were identified to species level whenever possible with the aid of photographic fish guides[20–23] and their body lengths were visually estimated to the nearest centimeter. The abundance of each species of a particular size was estimated by actual counts or by cluster in the case of a school of fish. The biomass of each species was then computed using the formula ***W=aLb*** where ***W*** is the weight in grams, ***L*** is the length of the fish in centimeters, and ***a*** and ***b*** are the species-specific growth constants derived from the length-weight relationships[24–28]. Abundance and biomass data were then converted and represented as density by individuals/100m^2 and biomass by kg/100m^2.

The counted fish were also attributed to trophic-level categories based on diet by species[27]. The correspondence between trophic levels and feeding habits is not strictly straightforward or well-defined because of wide overlaps in the food items consumed by different species[29]. Hence, the trophic levels under which a specific species is classified may be considered elastic and representative of the mean of its diet items. Trophic levels were expressed numerically and broadly represented herbivores (2.0–2.5), corallivores (2.6–3.0), planktivores (3.1–3.5), benthic carnivores (3.6 - 4.0), and piscivores (4.1–4.5)[30]. By analyzing the fish communities using trophic levels, we strived to understand the community structures and determine how fishing pressures might be affecting the fish communities. Fish in trophic levels 2.0-2.5 and 2.5-3.0 are typically small in size and are not considered important to local fisheries[31]. Fish that are classified in trophic levels 2.0-3.0 are usually important indicator species that contribute to the health of the reef by providing such services as cropping algal growth which otherwise would impede the settlement of juvenile corals[32,33]. These fish include damselfish, tangs, surgeonfish, butterflyfish, and a few small-bodied parrotfish. Fish in trophic level 3.0-3.5 and 3.5-4.0 include larger-bodied herbivores, planktivores, omnivores, or carnivores that feed on small benthic invertebrates. Fish classified in these ranges include wrasses, some species of butterflyfish, damselfish, hogfish, goatfish, snappers, and triggerfish. Fish in trophic level 4.0-4.5 are typically considered top predators and prey on finfish of the lower trophic levels. These predatory fish include large wrasse, grouper, hawkfish, snapper, goatfish, and sharks. The majority of the fish important to local fisheries are found in trophic levels 3.5-4.0 and 4.0-4.5[31].

By analyzing the fish communities using trophic levels, **we strived to understand the community structures** and determine how **fishing pressures might be affecting the fish communities.**

Figure 11 A SCIENTIFIC SCUBA DIVER RECORDS FISH ALONG A TRANSECT LINE. SCIENTIST RECORDS FISH OBSERVED ALONG A 30 M × 4 M TRANSECT OVER A 10-15 MINUTE PERIOD. PHOTO BY KEN MARKS.

3.0 RESULTS

3.1 HABITAT MAPPING

The Solomon Islands boasts a variety of marine habitats that play a critical role in the diversity and condition of the reefs. Habitats such as mangroves and seagrasses are important nursery and settlement sites for many reef and pelagic fish species[34,35]. Other mapped habitats encompassed the wave-exposed forereef habitats, lagoonal habitats, mudflats and macroalgae beds that all contribute to the varying community structures. The largest area mapped was Marovo lagoon which covers 450 km^2 (Table 3). Based on the forereef slope and size of the lagoon, the rest of the areas mapped varied in size by location from 25-307 km^2.

Reef-dominated lagoonal habitats accounted for 152 km^2 total of the areas mapped in the Solomon Islands. The dominant lagoonal habitat was barren lagoonal floor accounting for 55 km^2 of the total lagoonal area mapped. Given the geomorphology of the region, this is unsurprising with numerous large lagoons found here. Lagoons typically have a different reef community structure than what is found on the forereef. In the Solomon Islands, lagoonal fringing reefs and lagoonal pinnacle reefs dominated by massive coral were the most common reef habitats within the lagoons (Table 3).

Global Reef Expedition scientists **mapped 3,089 km^2** of **coral reefs** and surrounding shallow-water marine habitats in the **Solomon Islands**.

The lagoonal fringing reefs accounted for 76 km^2 of the reef structure and were mapped at all of the areas surveyed with the exception of the Reef Islands. Lagoonal fringing reefs are coral reef frameworks that fringe islands. These reefs have similar benthic community composition as lagoonal patch reefs. Lagoonal pinnacle reefs dominated by massive corals covered 60 km^2 of the area mapped. Lagoonal pinnacle reefs are typically built up by massive corals in the infant stages, such as *Porites spp.*, then settled upon by the smaller branching species like *Acroporids* and *Pocilloporids*. These reefs are typically found in shallower waters of the lagoon, surrounded by sediment. Vanikoro, Utupua, and Marovo were the areas with the highest lagoonal massive dominated pinnacle and fringing reef areas mapped (Table 3). Marovo lagoon was the only area mapped with pinnacle reefs dominated by branching coral. This habitat is similar to the lagoonal pinnacle reefs dominated by massive coral with the exception that they are developed and dominated by branching corals such as *Acroporids* and *Pocilloporids*.

Forereef habitats accounted for 155 km^2 of the reef habitat mapped in the Solomon Islands. The forereef habitats included deep forereef slope, shallow forereef terrace, and shallow forereef slope. These three habitats generally have a benthic community that is highly diverse and coral-dominated with a substantial macroalgae community. Deep forereef slopes have a dominant scleractinian (hard coral) community that differs among locations with some of the shallower areas having a combination of branching *Acroporids* and massive and submassive *Porites* colonies. Malakobi had a notably expansive forereef area measuring 56 km^2.

The marine vegetation habitats that were prevalent in the Solomon Islands were mangroves and seagrasses. Both habitats are important marine habitats typically found adjacent to coral reef communities. These habitats were both observed in all of the areas mapped with the exception of mangroves being absent from Marovo sites. The Reef Islands had the largest area of dense seagrass, covering over 2 km^2. Mangroves were most prevalent in Vanikoro and Utupua.

Table 3 TOTAL AREA (KM^2) OF HABITAT TYPE, BY ISLAND, CALCULATED FROM HABITAT MAPS. DASHES INDICATE NO HABITAT TYPE FOUND AT THAT LOCATION.

	TOTAL AREA (SQUARE KM)								
HABITAT CLASSIFICATIONS	Gizo	Malakobi	Reef Islands	Sikopo-Kerehikapa	Tinakula	Munda	Marovo	Utupua	Vanikoro
Back reef coral bommies	0.23	0.00	1.00	0.01	--	0.03	--	0.23	--
Back reef coral framework	1.62	0.88	4.29	0.12	--	1.48	0.71	2.47	3.59
Back reef - pavement	1.97	8.94	19.30	0.69	--	1.35	4.00	4.74	14.69
Back reef - rubble dominated	3.88	6.61	20.14	0.73	--	1.97	2.68	5.52	7.61
Back reef - sediment dominated	2.07	5.59	9.94	0.24	--	1.47	2.13	1.69	0.68
Deep forereef slope	4.67	20.42	8.99	7.18	0.38	0.72	1.20	3.01	6.34
Dense macroalgae on sediment	0.86	2.79	4.51	0.20	--	--	2.32	--	2.68
Dense seagrass meadows	1.21	0.18	2.23	0.31	--	0.90	0.29	1.35	0.70
Forereef sand flats	3.00	8.41	4.57	0.41	0.38	0.01	--	1.59	2.23
Inland waters	0.04	--	--	--	--	--	--	--	--
Lagoonal Acropora framework	0.02	--	--	--	--	--	--	--	--
Lagoonal floor - barren	7.62	23.51	34.19	1.96	--	6.44	99.12	8.42	17.01
Lagoonal floor - coral bommies	0.12	0.06	0.64	0.00	--	0.08	0.49	0.17	0.03
Lagoonal fringing reefs	3.20	6.03	--	1.37	--	0.97	32.46	11.73	20.58
Lagoonal patch reefs	0.21	0.29	2.12	0.07	--	0.28	0.60	0.27	2.22
Lagoonal pinnacle reefs - branching coral dominated	--	--	--	--	--	--	8.50	--	--
Lagoonal pinnacle reefs - calcareous red algal conglomerate	0.20	1.98	0.39	0.02	--	1.46	1.92	--	--
Lagoonal pinnacle reefs - massive coral dominated	2.89	10.61	2.72	0.24	--	4.21	29.14	1.92	8.74
Lagoonal sediment apron - macroalgae on sediment	2.60	--	0.03	0.29	--	0.76	0.89	--	--
Lagoonal sediment apron - sediment dominated	3.43	1.23	2.36	0.12	--	2.96	17.66	0.92	1.37
Mangroves	2.70	1.44	1.17	1.07	--	0.07	--	10.13	16.33
Mud flats	0.26	0.01	0.76	0.48	--	0.20	0.03	1.83	2.19
Reef crest	0.38	0.72	3.41	0.21	0.14	0.22	0.09	0.75	1.71
Shallow forereef slope	5.47	21.20	8.52	6.15	--	1.08	1.10	3.90	6.76
Shallow forereef terrace	3.55	14.39	4.18	2.58	--	0.83	3.20	8.56	11.59
Terrestrial vegetation	32.65	6.90	24.88	1.07	5.41	9.52	240.96	61.92	175.83
Unvegetated terrestrial	0.65	0.09	1.81	0.37	2.43	0.42	1.27	0.66	4.44
Urbanized areas	0.66	--	--	--	--	0.76	0.10	--	--
Total	**10.14**	**30.89**	**20.82**	**--**	**0.06**	**6.35**	**0.20**	**0.36**	**0.92**

3.2 BENTHIC COMMUNITIES

The benthic and fish communities at 68 sites within the Western, Isabel, and Temotu provinces were studied during the KSLOF mission to the Solomon Islands. The benthic communities of the Solomon Islands were in unexpectedly poor condition and inconsistent in overall live coral cover. Given the proximity to the Coral Triangle, high percentages (>40%) of live coral cover[36] would be expected in the Solomon Islands, however, overall, this was not the case for the sites surveys. Additionally, there was a higher presence of erect calcareous algae (primarily *Halimeda spp.*) at depth (>15 m) which is known to reduce the successful recruitment of coral larvae to an area[37]. With higher wave action, the erect calcareous algae can agitate the substrate, preventing larvae from successfully settling and developing. Some sites had evidence of recent Crown-of-Thorns Starfish outbreak damage with many scars being observed on the surviving corals.

3.2 a WESTERN PROVINCE

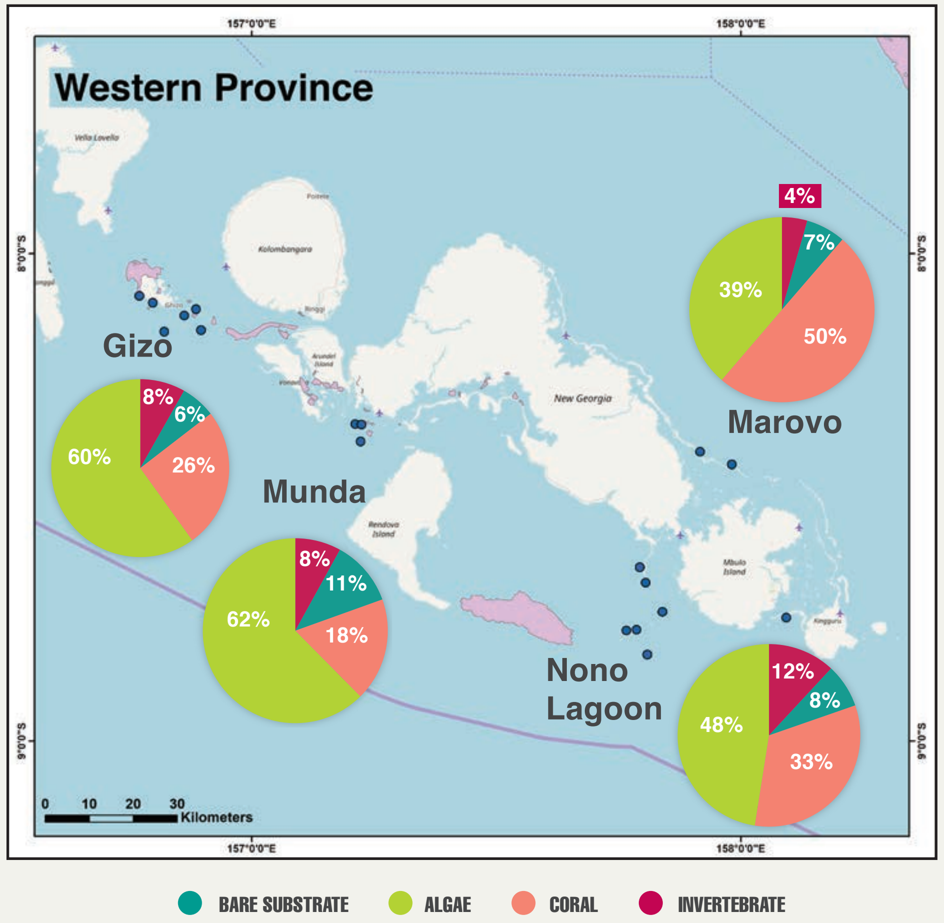
In the Western province, KSLOF surveyed sites near Gizo, Marovo, Munda, and Nono Lagoon. These areas had an average live coral cover ranging from 18-49% (Figure 12). The sites with the highest live coral cover in the Western Province and second overall were near Marovo measuring an average of 49% (± 7% S.D., n=8 transects) live coral. Both of the sites surveyed at Marovo were on the exposed side of the fringing reef, typically where higher coral cover is observed; no sites within the lagoon were surveyed. Marovo had an average of 38% (± 2% S.D., n=8 transects) algae with the majority (51% ± 12% S.D.) being composed of crustose coralline algae (Figure 13). Crustose coralline algae (CCA) is a common settlement site for coral polyps which is important for the long-term growth and stability of the reef[37,38]. The sites surveyed at Marovo were nearly absent from erect coralline algae which was commonly found in the rest of the sites surveyed within the Solomon Islands.

The sites with the lowest live coral cover were found near Munda. This area had an average of 18% (± 9%, n=43) live coral cover (Figure 12). Bare substrate near Munda, meaning substrate absent of sediments, algae, live coral, or sessile invertebrates, accounted for 11% (±7% S.D.) of the measurements. This was near average of what was observed in all of the Solomon Islands. Munda had an algal community dominated by CCA (40% ± 4% S.D.) and turf algae (31% ± 8% S.D.; Figure 13). An overabundance of macroalgae might be indicative of higher nutrients or an unstable invertebrate and fish community, however, this does not appear to be the case in Munda. The dominance of CCA and turf indicates the fish and invertebrate community is likely contributing to the lower macroalgal presence. There was, however, a higher presence of cyanobacteria presence, accounting for 3% (±4% S.D.) of the total algae observed.

The majority of the survey effort in the Western province was spent around the island of Gizo. Most of the reefs around Gizo have special protections in place (Figure 12)[13] to reduce fishing pressures from the communities. The live coral cover measured here was 25% (± 9% S.D., n=78 transects; Figure 12). The sites surveyed on the southeast, outer fringing reef had the highest live coral cover, ranging from 30-33%. Gizo's reefs were all dominated by algae, covering 59% (± 11% S.D.) of the total substrate. This area had the lowest average percentage of CCA (31% ± 6% S.D.) with the dominant algae instead being turf (39% ± 4% S.D.). The area also had the highest percentage of erect coralline algae in the province accounting for 11% (±11% S.D.) of the total algae recorded. Erect coralline algae, most notably *Halimeda spp.* was commonly found throughout the Solomon Islands, particularly at depths deeper than 15 meters.

Nono Lagoon was the last area surveyed in the Western province. This area had an average overall live coral cover of 32% (±12 % S.D., n=37 transects; Figure 12). The individual site averages of live coral cover ranged widely, from 20-50%. Generally, this area had the highest percentage of sessile invertebrates in the Solomon Islands, measuring an average of 12% (±7% S.D., n=37 transects). The dominant sessile invertebrates included leather corals, sponges, and other soft corals such as *Sacrophotons* and *Sinularia*. The algal community within Nono Lagoon was dominated by CCA which accounted for 47% (±6% S.D., n=37 transects) of the total algae observed, with the next most dominant algae being turf algae accounting for 29% (±8% S.D., n=37 transects) of the total algae (Figure 13). The coral diversity in the Western province was evenly spread among common reef-building genera including *Porites*, *Acropora*, *Montipora*, *Pocillopora*, *Millepora*, and *Turbinaria*. When analyzing the Simpson Index of Diversity, the closer the value is to 1, the more diverse the area. Having a diversity close to 1 is expected because of the region's inclusion in the Coral Triangle where the highest diversity in the world is commonly found. Nono Lagoon had a high diversity index of 0.90. There was a much lower presence of *Millepora*, a more "weedy" coral, in Nono Lagoon which could have contributed to the higher diversity observed here because its absence may have allowed other coral genera to grow. Gizo and Marovo had nearly identical diversity of 0.87, however, they had very different coral community compositions. Isopora was one of the most abundant coral genera observed in Gizo. Marovo was dominated by *Acropora*, followed by *Porites*, *Montipora*, *Millepora*, and *Echinopora*. Munda had a lower diversity index of 0.81. This area was dominated by *Porites*, *Pachyseris*, *Montipora*, and *Acropora*.

Figure 12 AVERAGE BENTHIC COVER (%) OF EACH ISLAND SURVEYED IN THE WESTERN PROVINCE, SOLOMON ISLANDS. THE SUBSTRATE TYPES ARE BARE SUBSTRATE, ALGAE, LIVE CORAL, AND INVERTEBRATES. NOTE THAT INVERTEBRATES DO NOT INCLUDE HARD SCLERACTINIAN CORALS, AND INSTEAD INCLUDE ALL OTHER SESSILE INVERTEBRATES SUCH AS ANEMONES, SOFT CORALS, GORGONIANS, CLAMS, ETC. THESE VALUES WERE CALCULATED FROM THE BENTHIC SURVEYS, AVERAGING BY DEPTH, THEN SITE. NUMBER OF TRANSECTS (N) AT EACH LOCATION: GIZO, N=78; MAROVO, N=8; MUNDA, N=43; NONO LAGOON, N=37.



3.2 b ISABEL PROVINCE

Isabel province's main island is Santa Isabela, located east of the Western province. In the northwestern region of the province, bordering Choiseul Province, is the Arnavon Islands marine conservation area. KSLOF surveyed around Kerehikapa and Sikopo, both found within the boundaries of the conservation area, as well as the area around Malakobi, which lies outside the protected region.

Kerehikapa is the furthest south cay within the Arnavon Islands marine conservation area. This area had an average of 51% live coral cover (± 17% S.D., n=19 transects) with the highest average live coral cover of all areas surveyed in the Solomon Islands (Figure 14). One site, in particular, had the highest overall with 69% (± 5% S.D., n=8 transects) live coral cover, some of the highest observed on the entire Global Reef Expedition. Algae accounted for an average of 30% (±14% S.D., n=19 transects) of the remaining substrate around Kerehikapa and was composed predominately of CCA and turf algae. These algae combined accounted for 67% of the total algae measured around Kerehikapa (Figure 13). Invertebrates covered 10% (±3% S.D., 19 transects) of the substrate, leaving 7% (±6% S.D., n=19) bare.

The second area surveyed within the Arnavon Islands Marine Conservation Area was Sikopo. This cay had a much lower average live coral cover, measuring only 30% (±10% S.D., n=20 transects) when compared to Kerehikapa. Interestingly, this site had a higher percentage of bare substrate, accounting for 29% (±10% S.D., n=20 transects) of the total benthic substrate (Figure 14). The reef system around Sikopo was patchy with notable amounts of rubble and sand interspersed around the cay, at all depths, and very little reef structure throughout. It is possible that the tsunami in April 2007 may have affected this reef more than Kerehikapa, but further investigation into this is suggested. Algae was the most abundant substrate recorded, accounting for 36% (13% S.D., n=20 transects) of the benthos. The algal community was dominated by both turf, and turf mixed with sediment, accounting for 54% of the total algae observed, combined (Figure 13). The higher turf and turf with sediment are expected given the amount of rubble and sand found at this site.

The area outside of the Arnavon Islands Marine Conservation Area, and the most northern end of Santa Isabel Island, is Malakobi. Within this area, KSLOF surveyed sites both within and outside of the lagoon. Live coral cover was lower than even Sikopo, with only 26% (±12% S.D., n=38 transects; Figure 14) live coral found in the benthos. It is worth noting, live coral cover ranged drastically from 8-45% among the sites surveyed. On average, algae dominated the substrate, covering a total of 52% (±12 S.D., n=38 transects) of the substrate (Figure 13). The average algal cover was evenly spread among CCA, erect coralline algae, macroalgae, turf, and turf with sediment. In the Malakobi region, the farthest west sites were dominated by *Halimeda spp.* and turf with sediment. They also had low relief reef structure with the lowest live coral cover and only small, fist-sized corals being observed. It is possible that the tsunami may have damaged these reefs as what was observed on Sikopo. Generally, in both areas, it was observed that the further south and east, and closer to the Santa Isabel, the higher the live coral cover was observed.

The coral diversity in the Arnavon Islands conservation area ranged from 0.77-0.88. Kerehikapa had a lower coral diversity of 0.77, possibly due to the dominance of *Acropora* and *Porites*. These two dominant genera accounted for over 40% of the coral observed in this area. The dominant genera around Sikopo were *Porites* and *Montipora*, with a notable presence of *Cyphastrea*. Although it was not a dominant genus, compared to other regions of the Solomon Islands, Sikopo had the most *Cyphastrea* measured. Malakobi had a higher diversity of 0.88. This area was dominated by *Acropora*, *Isopora*, and *Porites*.

Figure 13

RELATIVE COMPOSITION (%) OF ALGAE (CRUSTOSE CORALLINE ALGAE (CCA), CYANOBACTERIA (CY), ERECT CALCAREOUS ALGAE (E), MACROALGAE (M), TURF (T), AND TURF WITH SEDIMENT (TS) AT EACH SITE SURVEYED IN THE SOLOMON ISLANDS. THE DATA PRESENTED IS AVERAGED ACROSS DEPTH FROM DATA COLLECTED ON THE BENTHIC TRANSECTS AT EACH SITE. THE NUMBER (N) OF TRANSECTS AVERAGED AT EACH SITE: GIZO, N=78; MAROVO, N=8; MUNDA, N=43; NONO LAGOON, N=37; KEREHIKAPA, N=19; MALAKOBI, N=38; SIKOPO, N=20; REEF ISLANDS, N=108; TINAKULA, N=12; UTUPUA, N=61; VINAKORO, N=49.

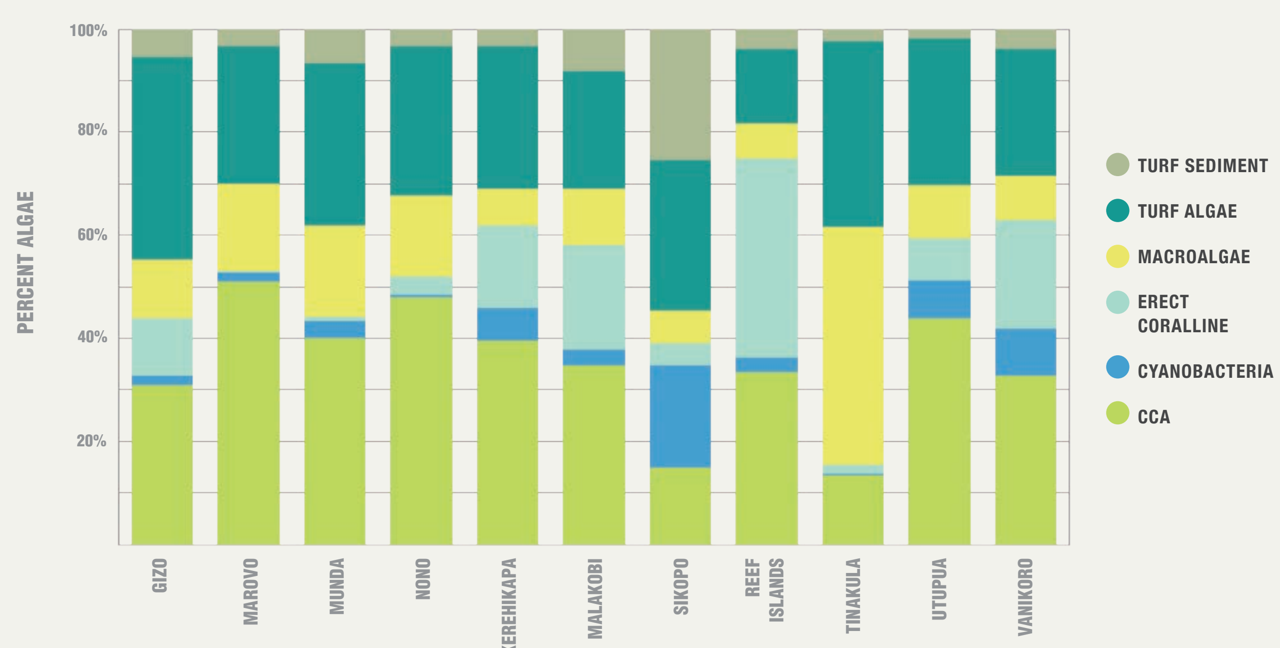
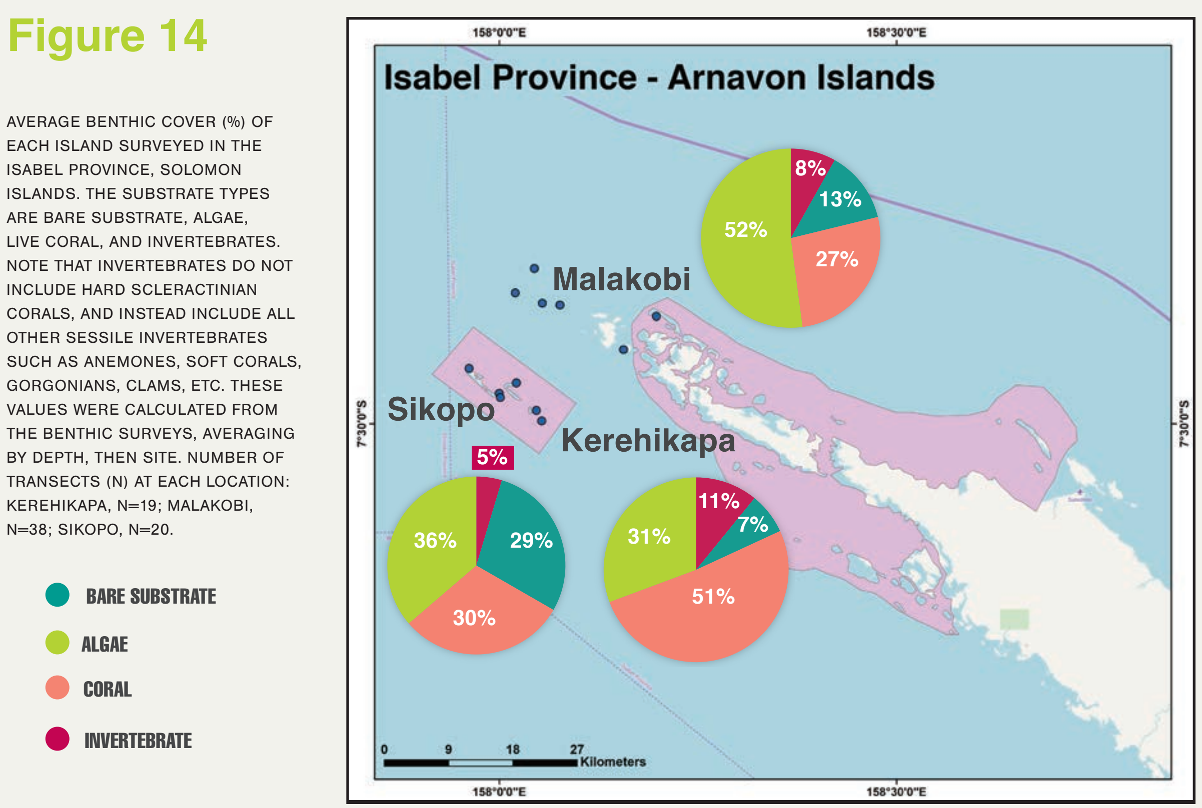


Figure 14

AVERAGE BENTHIC COVER (%) OF EACH ISLAND SURVEYED IN THE ISABEL PROVINCE, SOLOMON ISLANDS. THE SUBSTRATE TYPES ARE BARE SUBSTRATE, ALGAE, LIVE CORAL, AND INVERTEBRATES. NOTE THAT INVERTEBRATES DO NOT INCLUDE HARD SCLERACTINIAN CORALS, AND INSTEAD INCLUDE ALL OTHER SESSILE INVERTEBRATES SUCH AS ANEMONES, SOFT CORALS, GORGONIANS, CLAMS, ETC. THESE VALUES WERE CALCULATED FROM THE BENTHIC SURVEYS, AVERAGING BY DEPTH, THEN SITE. NUMBER OF TRANSECTS (N) AT EACH LOCATION: KEREHIKAPA, N=19; MALAKOBI, N=38; SIKOPO, N=20.



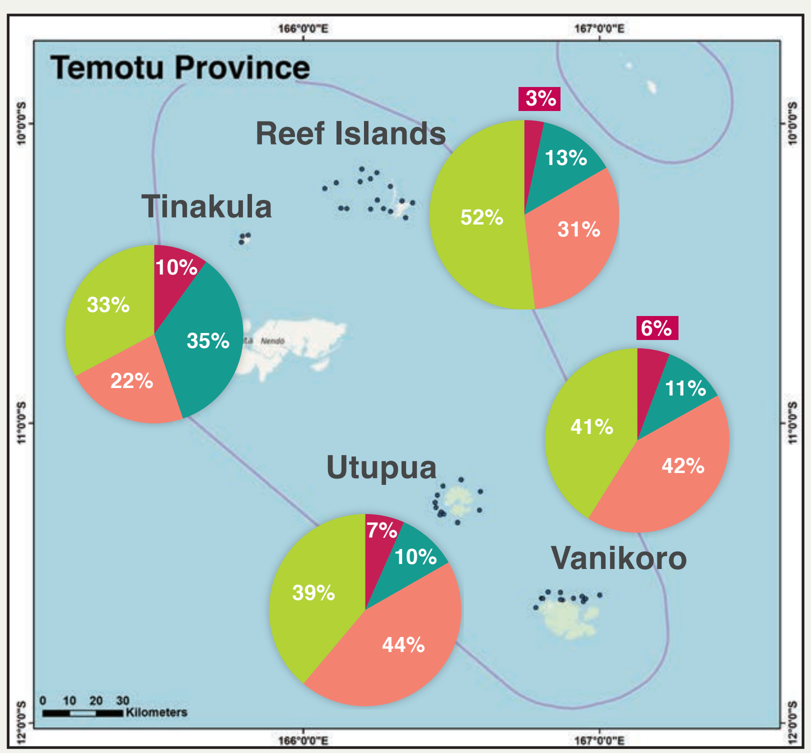
3.2 c

TEMOTU PROVINCE

The Temotu Province is one of the most isolated and difficult to reach provinces in the Solomon Islands. It is the farthest southeast and receives minimal visitation from tourists and industry. There is a combination of uplifted reef islands, sand cays, and volcanic islands found in this area, with an active volcano, Tinakula, which we surveyed. This area is one of the most understudied regions in the Solomon Islands, making it a priority region for the GRE and where the majority of the study time was dedicated. In the Temotu Province, KSLOF surveyed around the Reef Islands, Utupua, Vanikoro, and Tinakula. With Tinakula erupting in 2012, only two years prior to our survey effort, there is an essentially new reef system beginning to form around half of the island, making it a unique place to study and nearly incomparable to the older more developed reefs in the province.

The Reef Islands are a conglomerate of small, uplifted coral islands with the majority of the reef structures being found in the lagoon, see **Table 3**. This area had an average live coral cover of 31% (±8% S.D., n=108 transects) with algae covering the majority (51% ± 7% S.D., n=108 transects) of the benthos **(Figure 15)**. This area had the highest percentage of erect coralline algae of all the areas surveyed in the Solomon Islands, particularly abundant with *Halimeda spp.* that accounted for 38% (±13% S.D., n=108 transects) of the total algae measured **(Figure 13)**. *Halimeda* was found at all depths, but in particularly large patches at depths deeper than 10 meters. At nearly all sites, there was a disparity between depths greater and less than 10 meters regarding the benthic communities. There was notably higher live coral cover observed at depths shallower than 10 meters, while deeper reefs had much higher algal cover. The average live coral cover at depths shallower than 10 meters was 51% (±12, n= 15 transects), 20% higher than the average for all sites. KSLOF did find evidence of COTS and removed a total of 182 individuals from the reefs indicating an active outbreak was occurring which could be detrimental to the reef if it had worsened since our departure.

Figure 15



AVERAGE BENTHIC COVER (%) OF EACH ISLAND SURVEYED IN THE ISABEL PROVINCE, SOLOMON ISLANDS. THE SUBSTRATE TYPES ARE BARE SUBSTRATE, ALGAE, LIVE CORAL, AND INVERTEBRATES. NOTE THAT INVERTEBRATES DO NOT INCLUDE HARD SCLERACTINIAN CORALS, AND INSTEAD INCLUDE ALL OTHER SESSILE INVERTEBRATES SUCH AS ANEMONES, SOFT CORALS, GORGONIANS, CLAMS, ETC. THESE VALUES WERE CALCULATED FROM THE BENTHIC SURVEYS, AVERAGING BY DEPTH, THEN SITE. NUMBER OF TRANSECTS (N) AT EACH LOCATION: REEF ISLANDS, N=108; TINAKULA, N=12; UTUPUA, N=61; VINAKORO, N=49.

BARE SUBSTRATE
ALGAE
CORAL
INVERTEBRATE

Figure 16

PHOTOGRAPH OF THE ACTIVE VOLCANO, TINAKULA, IN THE TEMOTU PROVINCE, SOLOMON ISLANDS. THE ERUPTION PRIMARILY IMPACTED THE REEFS ON ONLY ONE SIDE OF THE ISLAND.

Vanikoro and Utupua are both small atolls found within the Temotu province. Both of these sites had relatively high live coral cover ranging from 42% (±8% S.D., n=49 transects) to 44% (±11% S.D., n=61 transects) respectively, which were the highest percentages found within the province and in nearly all the Solomon Islands **(Figure 15)**. Utupua had an average of 38% (±9% S.D., n=61 transects) algae present, dominated by CCA. CCA accounted for 44% (±16% S.D., n=61 transects) of the algae observed, with the least amount of erect coralline algae for the developed reef system. Tinakula had less, but since it's still a newly developing reef system since the eruption, it's not considered comparable. Vanikoro was also dominated by CCA (32% ± 17% S.D., n=49 transects), however, there was a notable amount of erect coralline algae, particularly *Halimeda spp.*, accounting for 21% (±15% S.D., n=49 transects) of the total algae observed.

Tinakula is an active volcano in the Temotu province that had a major eruption in February 2012, two and a half years prior to the KSLOF visit to the Solomon Islands. As seen in **Figure 16**, the eruption most significantly impacted half of the island. Since then, there has been at least one other eruption documented, so it is doubtful the findings of this report are still accurate. Regardless, at the time of the surveying effort, KSLOF completed 12 transects around the volcanic island and found it had an average of 22% (±16% S.D., n=12 transects) live coral cover remaining **(Figure 15)**. We observed many new recruits on the large boulders that had been deposited on the side most significantly impacted by the eruption. Algae accounted for 32% (±10% S.D., n=12 transects) of the substrate, dominated by macroalgae and turf algae, combined measuring 82% of the algae recorded **(Figure 13)**. There was only 13% (±6% S.D., n=12 transects) CCA present.

The Temotu province is the most remote region of the Solomon Islands and had some of the highest coral diversity when compared to the other two provinces. The diversity ranged from 0.88-0.90. Vanikoro had a diversity of 0.90 and was dominated by *Acropora* and *Porites*, although a total of 40 different genera were observed here. This is an exceptional variety of coral observed and was one of the most diverse areas observed on the entire GRE. Despite half of the substrate being an essentially new reef, Tinakula had a diversity index of 0.90. This site had was dominated by *Acropora, Montipora, Millepora*, and *Porites*. The Reef Islands had a diversity of 0.89. The Reef Islands were dominated by *Acropora* and *Porites*. Utupua had a diversity of 0.88 and was dominated by *Acropora* and *Proites*, combined accounting for 39% of the coral measured in this area.

3.3 FISH COMMUNITY ASSESSMENT

The fish communities in the Solomon Islands showed distinctive patterns across sites, which likely reflected patterns in fishing pressure across the archipelago. Fish communities tended to be more abundant, diverse, and have larger fish present in the Temotu Province, where human population density, and therefore, fishing pressure, is lower. Gizo, a populated region in the Western Province, consistently had the lowest overall values for all metrics, and the smallest fish on average (Table 4). Conversely, the Reef Islands had the healthiest fish communities, with the highest species richness, fish density, and biomass at this site (Table 4).

> The Reef Islands had the **healthiest fish community** with the **highest species richness, fish density,** and **biomass** of all sites surveyed in the Solomon Islands.

Table 4 SAMPLING INTENSITY, DIVERSITY, AND ESTIMATED MEAN SPECIES RICHNESS (NUMBER OF SPECIES/120 M^2), MEAN DENSITY (INDIVIDUALS/100 M^2), AND MEAN BIOMASS (KG/100 M^2) OF FISH AT 11 SITES IN THE SOLOMON ISLANDS.

LOCATION/ ISLAND	NUMBER OF SURVEY STATIONS	NUMBER OF REPLICATE TRANSECTS	TOTAL FAMILIES	TOTAL SPECIES	MEAN SPECIES RICHNESS	MEAN DENSITY	MEAN BIOMASS
Gizo	6.0	72.0	41.0	345.0	27.6	83.7	1.7
Kerehikapa	3.0	21.0	37.0	243.0	39.7	182.1	4.7
Malakobi	6.0	52.0	35.0	305.0	36.9	134.5	4.6
Marovo	2.0	19.0	30.0	220.0	36.6	146.1	3.4
Munda	3.0	32.0	36.0	275.0	32.7	101.6	3.1
Nono	7.0	67.0	42.0	365.0	34.6	131.6	3.3
Reef Islands	15.0	122.0	45.0	411.0	48.4	212.8	9.7
Sikopo	3.0	33.0	33.0	258.0	34.5	150.1	2.7
Tinakula	3.0	25.0	33.0	227.0	30.2	166.0	6.9
Utupua	11.0	96.0	39.0	389.0	40.0	191.5	4.7
Vanikoro	9.0	93.0	41.0	392.0	34.8	121.2	4.6
TOTAL	**69.0**	**640.0**	**55.0**	**653.0**			
MEAN	**5.8**	**53.3**	**36.3**	**297.5**	**37.4**	**145.7**	**4.3**

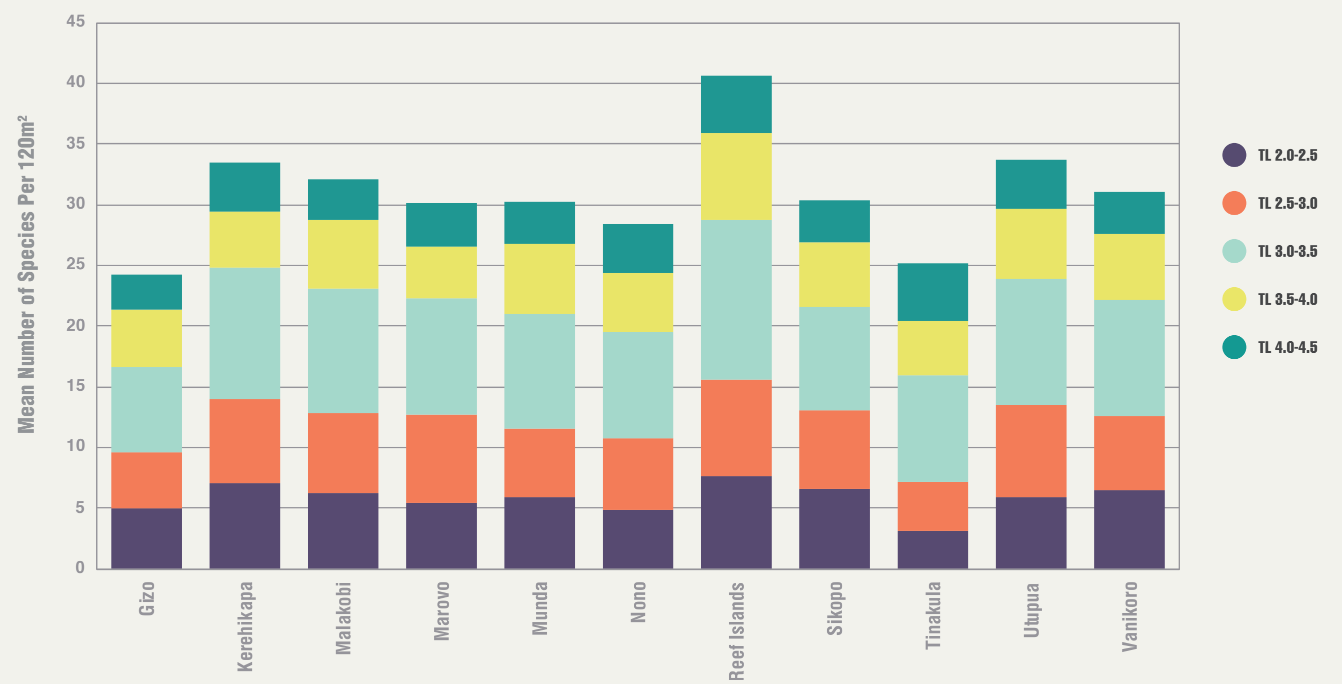
3.3 a SPECIES RICHNESS OF THE FISH ASSEMBLAGE

In total, 653 species from 55 different families were surveyed in the Solomon Islands during the research period (Table 4). The Reef Islands had the most diverse fish assemblage overall, and the highest mean values in all trophic categories except for the 4.0-4.5 category (Figure 17). Species richness in this trophic level was highest at Tinakula (4.7 species/120 m^2 +/- 2.7 SD), despite the overall richness at this location being the second-lowest of all of the sites.

Gizo had the lowest species richness overall, and the lowest value in trophic category 3.0-3.5 (7.0 species/120m^2 +/- 5.1 SD). Tinakula had the lowest species richness in the lower trophic categories (3.1 species/120m^2 +/- 2.2 SD in category 2.0-2.5 and 4.1 species/120m^2 +/- 2.7 SD in category 2.5-3.0), as well as category 3.5-4.0 (4.4 species/120m^2 +/- 2.7 SD) (Figure 17).

In general, overall species richness and relative values for each trophic level were quite similar at sites in the Western and Isabel Provinces, while sites in the Temotu Province exhibited a much wider range of values, both overall and by trophic level. Interestingly, this difference was most marked between the sites at the Reef Islands and Tinakula, despite the fact that these sites are located very close together geographically.

Figure 17 MEAN SPECIES RICHNESS (# OF SPECIES/120 M^2) BY TROPHIC LEVELS AT 11 SITES IN THE SOLOMON ISLANDS.



3.3 b FISH DENSITY

Overall, fish density was highest at the Reef Islands, despite the fact that the density values at this were distributed among all of the trophic categories (Figure 18). Similarly, overall density was lowest at Gizo; however trophic category 3.0-3.5 is the only category in which Gizo had the lowest value (35.7 individuals/100 m^2 +/- 42.1 SD).

Fish density at Tinakula was overwhelmingly dominated by fish in the 3.0-3.5 category (127.0 individuals/100 m^2 +/- 105.8 SD), while densities in the 2.0-2.5 and 2.5-3.0 trophic categories were the lowest of all the sites (6.1 individuals/100 m^2 +/- 5.9 SD and 12.0 individuals/100 m^2 +/- 14.1 SD, respectively). Conversely, fish density in the 4.0-4.5 category was the highest at this site, at 15.5 individuals/100 m^2 (+/- 20.5 SD). Marovo had the lowest density of predators in the 4.0-4.5 category (4.2 individuals/100 m^2 +/- 4.0 SD).

There was not a clear pattern in fish density when comparing sites in the Western and Isabel Provinces with those in the Temotu Province; however, there was a slight trend towards higher overall density in Temotu. Despite this, however, fish density in the lowest trophic category was highest in the Isabel and Western Provinces, with the highest density in the 2.0-2.5 category at Sikopo (39.5 individuals/100 m^2 +/- 35.1 SD).

3.3 c FISH BIOMASS

The Reef Islands sites had the highest overall fish biomass of all the sites. Biomass at this site was highest in trophic categories 2.0-2.5 and 2.5-3.0 (2.8 kg/100 m^2 +/- 3.1 SD and 1.0 kg/100 m^2 +/- 2.5 SD, respectively); the highest biomass in categories 3.5-4.0 and 4.0-4.5 was found at Tinakula (0.8 kg/100 m^2 +/- 1.5 SD and 4.9 kg/100 m^2 +/- 7.7 SD, respectively; Figure 19).

Gizo had the lowest biomass overall, with the sum of the biomass in all five trophic categories at this site totaling less than the biomass in category 2.0-2.5 at the Reef Islands alone. In particular, the biomass of fish in the lowest trophic level was particularly low at this site, at 0.6 kg/100 m^2 (+/- 0.8 SD). Sites in the Temotu Province tended to have higher biomass overall than those in the Isabel and Western Provinces. Notably, however, the biomass at Kerehikapa was on par with the biomass at Utupua and Vanikoro; in fact, biomass in the 3.0-3.5 category was highest at this site (1.4 kg/100 m^2 +/- 1.5 SD). This trend towards higher biomass in Temotu may be due to lower fishing pressure, due to the lower population density in the region.

Figure 18 MEAN DENSITY OF FISH (INDIVIDUALS/100 M²) BY TROPHIC LEVEL AT 11 SITES IN THE SOLOMON ISLANDS.

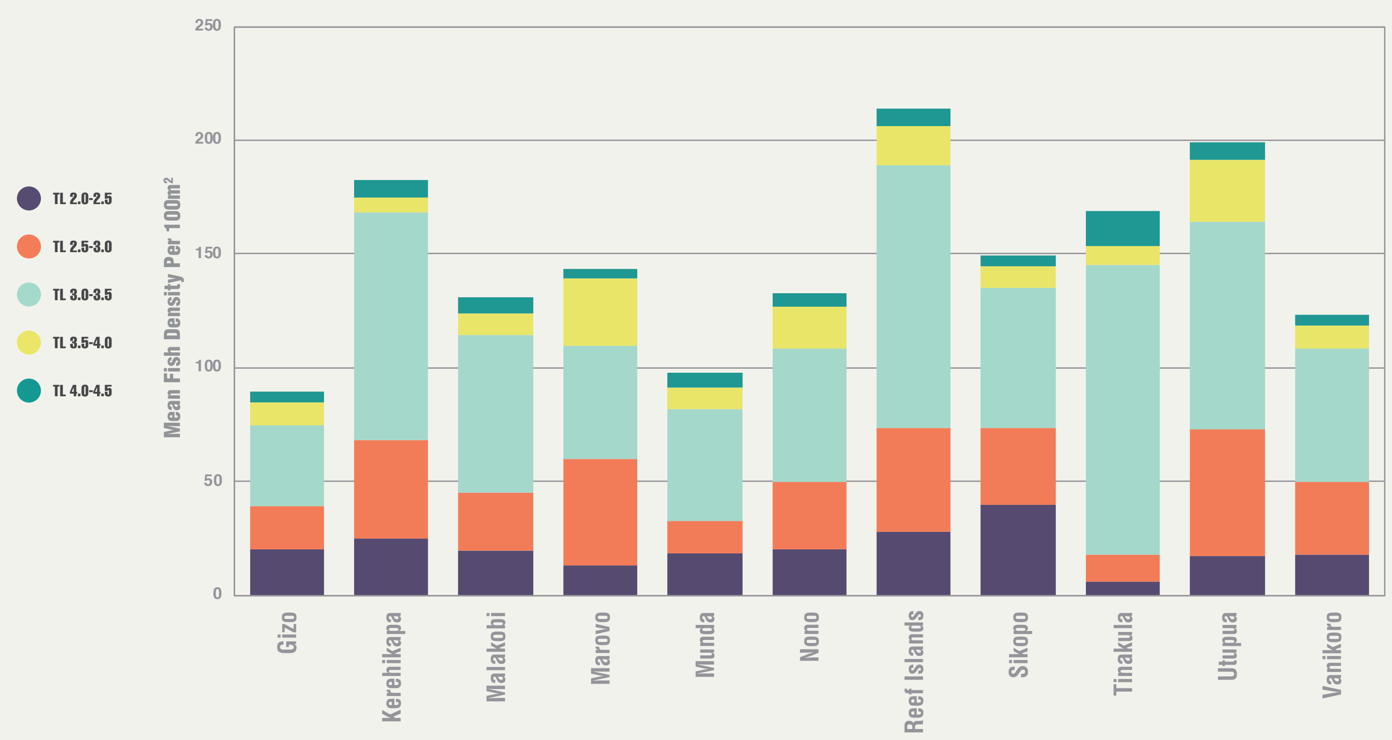
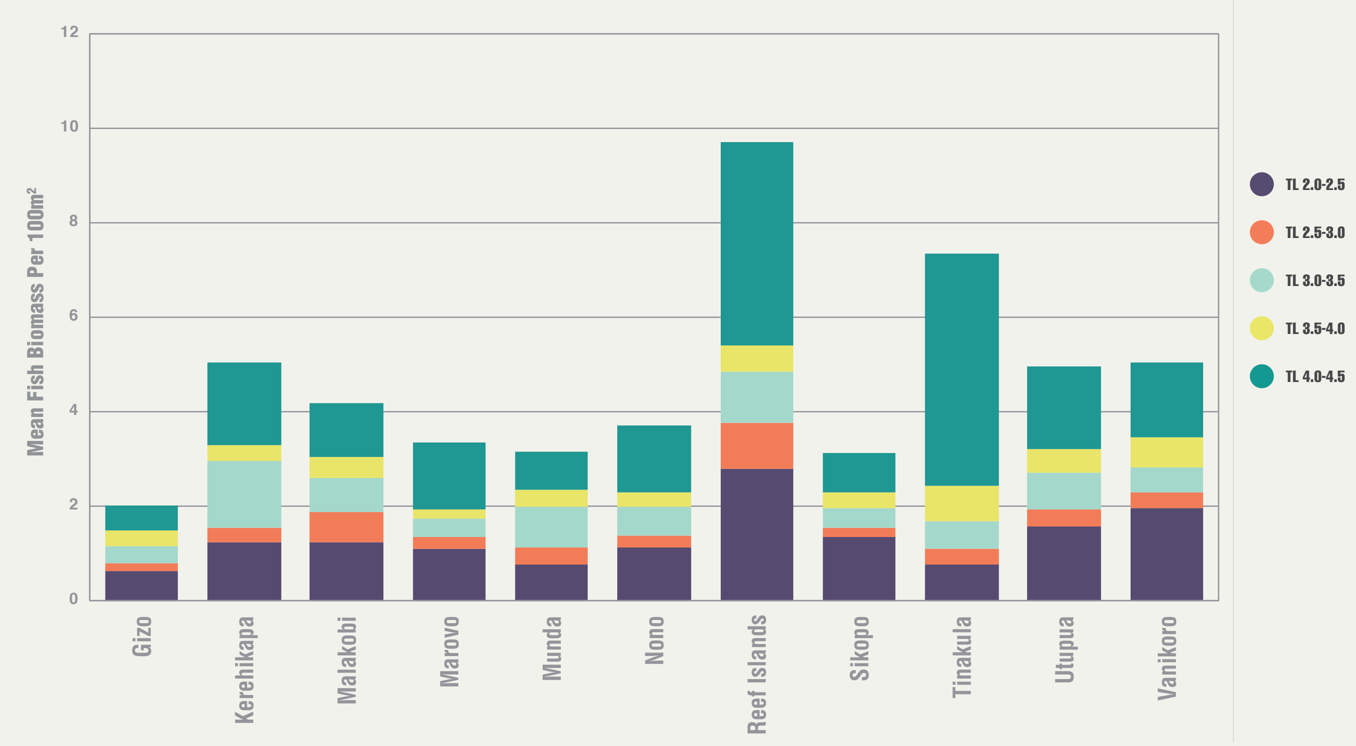


Figure 19 MEAN BIOMASS OF FISH (KG/100 M²) BY TROPHIC LEVEL AT 11 SITES IN THE SOLOMON ISLANDS.



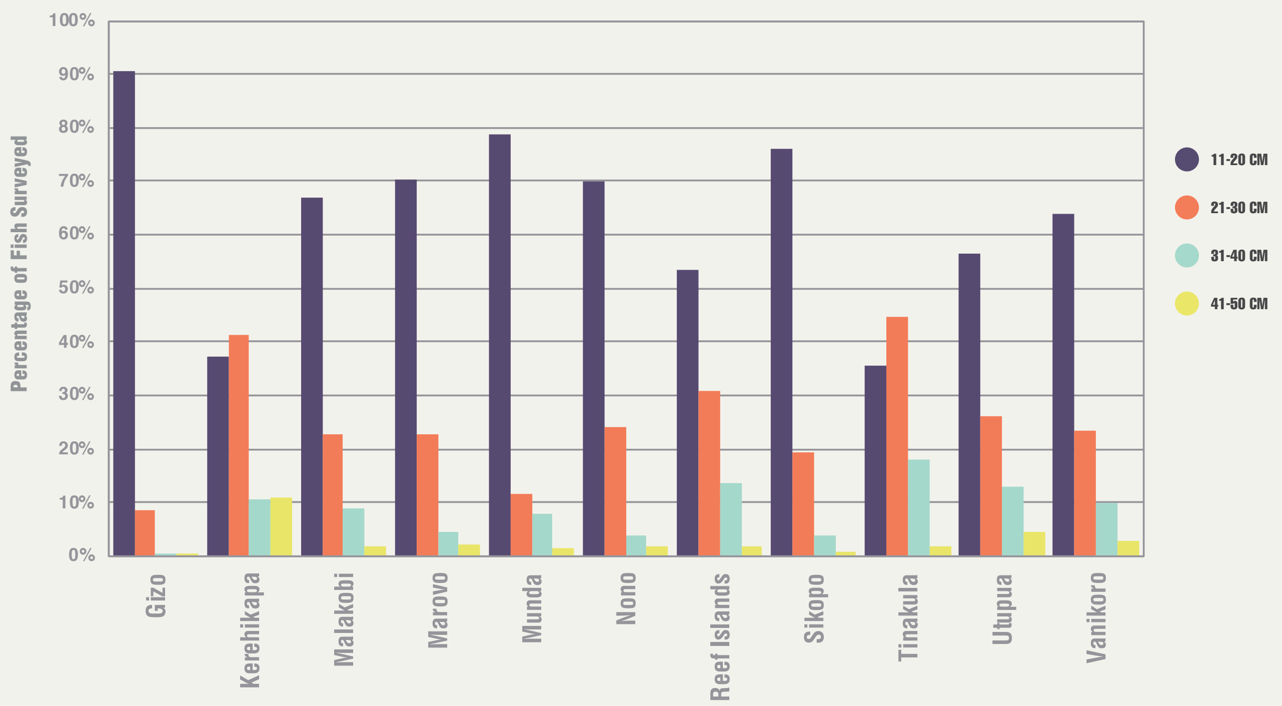
3.3 d SIZE DISTRIBUTION OF FISH

Small fish (11-20 cm) made up the largest proportion of fish surveyed at all sites except Kerehikapa and Tinakula, where the largest proportion of fish were 21-30 cm (Figure 20). Kerehikapa had the largest proportion of large fish (41-50 cm 10.9%), while Tinakula had the largest proportion of fish in the mid-size (21-30 cm and 31-40 cm) categories (44.7% and 18.0%, respectively).

Gizo had the largest proportion of small fish (11-20 cm; 90.6%), as well as the smallest proportion of mid-size fish (21-30 cm and 31-40 cm; 8.6% and 0.6%, respectively). Overall, fish at this site were the smallest on average.

With the exception of Kerehikapa, all of the sites in the Western and Isabel Provinces had higher proportions of small fish (11-20 cm) and lower proportions of 21-30 cm fish than those in the southeast. In general, the sites in the Temotu Province had a higher proportion of fish in the 31-40 cm category. There was not a clear pattern in the proportion of large fish (41-50 cm) between the provinces of the northwest (Western and Isabel) and the southeast (Temotu).

Figure 20 THE RELATIVE SIZE DISTRIBUTION (%) OF SELECTED IMPORTANT FISH FAMILIES AT 11 SITES IN THE SOLOMON ISLANDS. FAMILIES INCLUDED WERE: ACANTHURIDAE, CARANGIDAE, HAEMULIDAE, LETHRINIDAE, LUTJANIDAE, NEMIPTERIDAE, SCARIDAE, SERRANIDAE, AND SIGANIDAE. FISH WITH TOTAL LENGTHS BELOW 10CM AND GREATER THAN 50CM WERE EXCLUDED BECAUSE THEY WERE RARELY OBSERVED.



> The data collected on this mission will be **critical for monitoring changes** over time and **adapting management plans** to **better conserve** these habitats.

4.0

DISCUSSION

4.0

Each province visited in the Solomon Islands was different in some ways, yet similar in many others. The coral diversity of the Solomon Islands was consistently high with a total of 76 genera have been recorded in the area[2]. In the regions visited on the GRE, KSLOF scientists recorded a total of 54 of the expected coral genera in the transect measurements. When combining all sites, the coral diversity of the Solomon Islands is 0.89 which is, overall, some of the highest observed on the Global Reef Expedition.

The benthic communities of the Solomon Islands were very different across the archipelago. The overall live coral cover was unexpectedly low given its inclusion in the Coral Triangle. The Coral Triangle, in theory, is an optimal location for corals to grow and flourish, but both natural and anthropogenic factors may disrupt this. In the Solomon Islands, both of these disturbances were observed. Areas such as Gizo had overall lower coral cover while also having some of the largest villages in the Western province, indicating human impacts are affecting the nearshore reefs. However, in the protected Arnavon Islands, evidence of tsunami damage was observed which highlights impacts that natural disturbances can have. When compared to other regions studied on the GRE, the Solomon Islands had coral cover similar to other sites in the South Pacific (Figure 21). The Western province includes Gizo, Munda, Marovo, and Nono Lagoon. Combined, this province has the largest human population and had both some of the lowest and highest live coral cover recorded. Influences from human interactions with the reef are likely to explain the variability among the sites.

Around Munda, we observed evidence of excessive corallivore scarring, likely due to a Crown-of-Thorns Starfish (COTS) outbreak. COTS outbreaks are sometimes attributed to locally high nutrient runoff[39], and with Munda being one of the larger communities in the Western province, it is possible this may have contributed to this outbreak (Figure 22). This area also had the most cyanobacteria, most of which was found on the recently dead corals. Excessive nutrient runoff and previous overharvesting of macroinvertebrates such as sea cucumbers may be contributing to the cyanobacterial growth on the reef. Sea cucumbers are filter feeders that help regulate the cyanobacterial growth in the benthos[40]. Although we did not specifically measure the abundance of sea cucumbers in this area, this was a commercially important invertebrate who's fishery was closed in 2006[41].

Figure 21 GLOBAL COMPARISON OF PERCENT LIVE CORAL COVER AMONG COUNTRIES VISITED ON THE GRE.

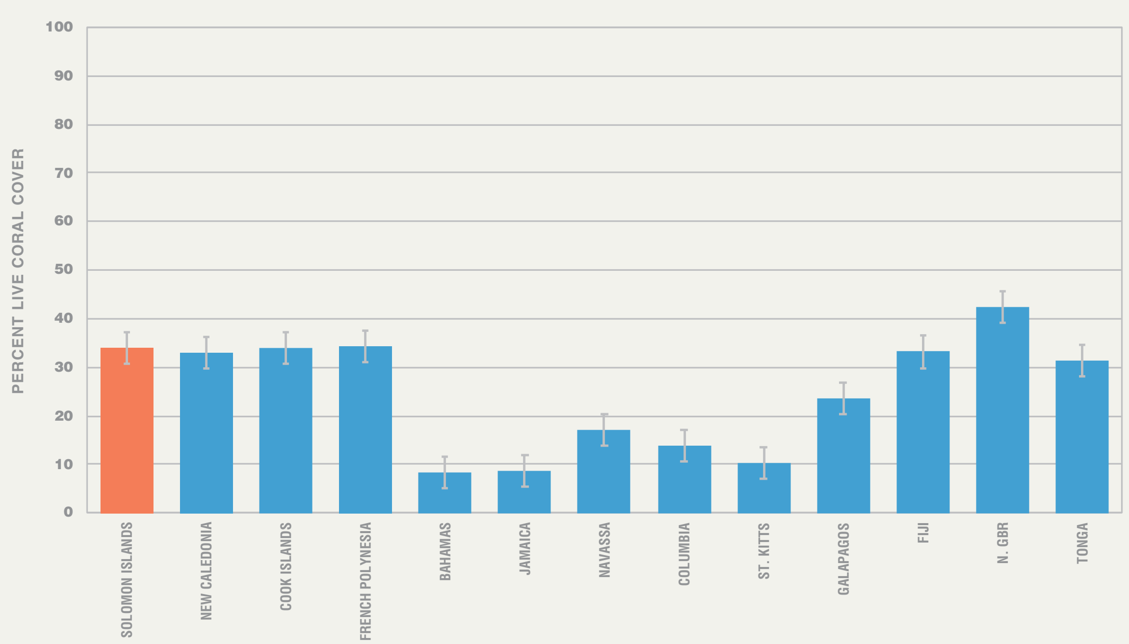
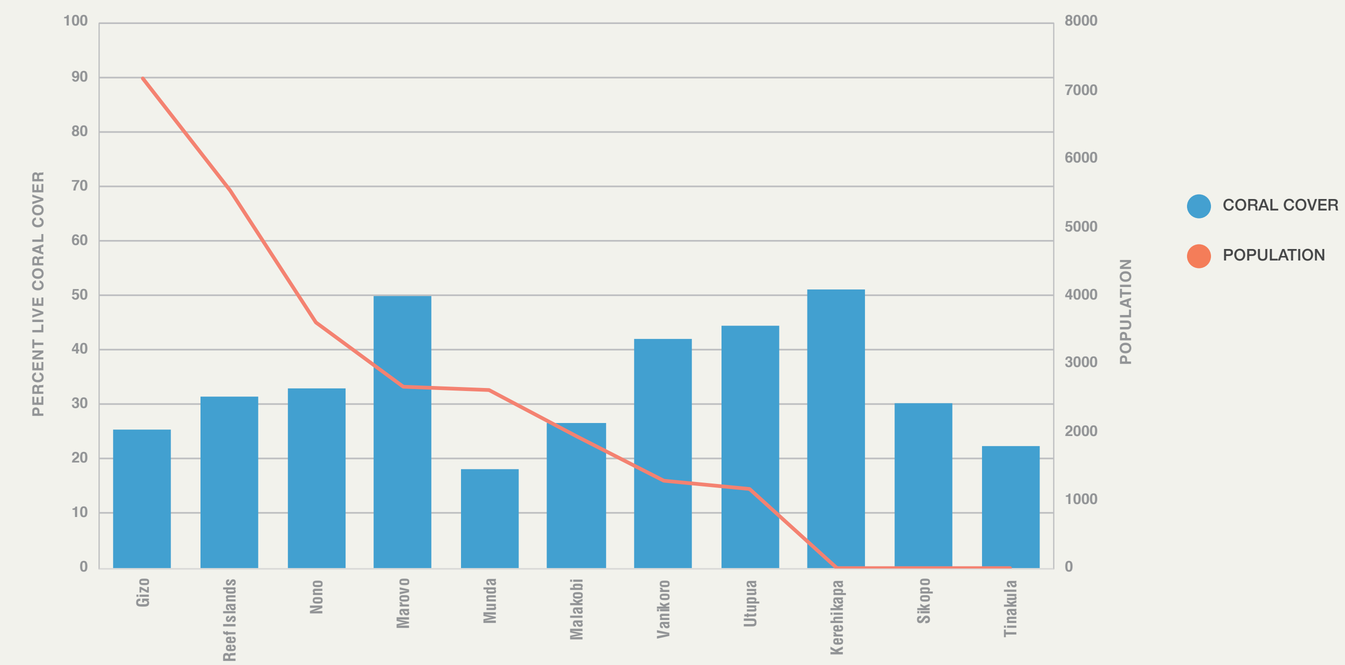


Figure 22 COMPARISON OF HUMAN POPULATION AGAINST PERCENT LIVE CORAL COVER FOR EACH LOCATION.



The Arnavon Islands appear to have been directly impacted by the magnitude 8.1 earthquake and tsunami in April 2007 who's epicenter was in the neighboring Western province. The tsunami's wave heights were reported as ranging from 2-10 m and significantly damaged many nearby reefs[42]. Sikopo had unexpectedly low coral cover, particularly when compared to the neighboring Kerehikapa. Large overturned coral heads and a higher percentage of rubble were observed, leading to the probability that significant damage was experienced here. Outside of the Arnavon protected area, Malakobi also appeared to be damaged by the same disturbance as this area had lower coral cover and evidence of damage as well.

Coral diversity in the **Solomon Islands** is some of the **highest observed** on the **Global Reef Expedition.**

Figure 23 GLOBAL COMPARISON OF FISH BIOMASS (KG/100M^2) OF COUNTRIES VISITED ON THE GRE.

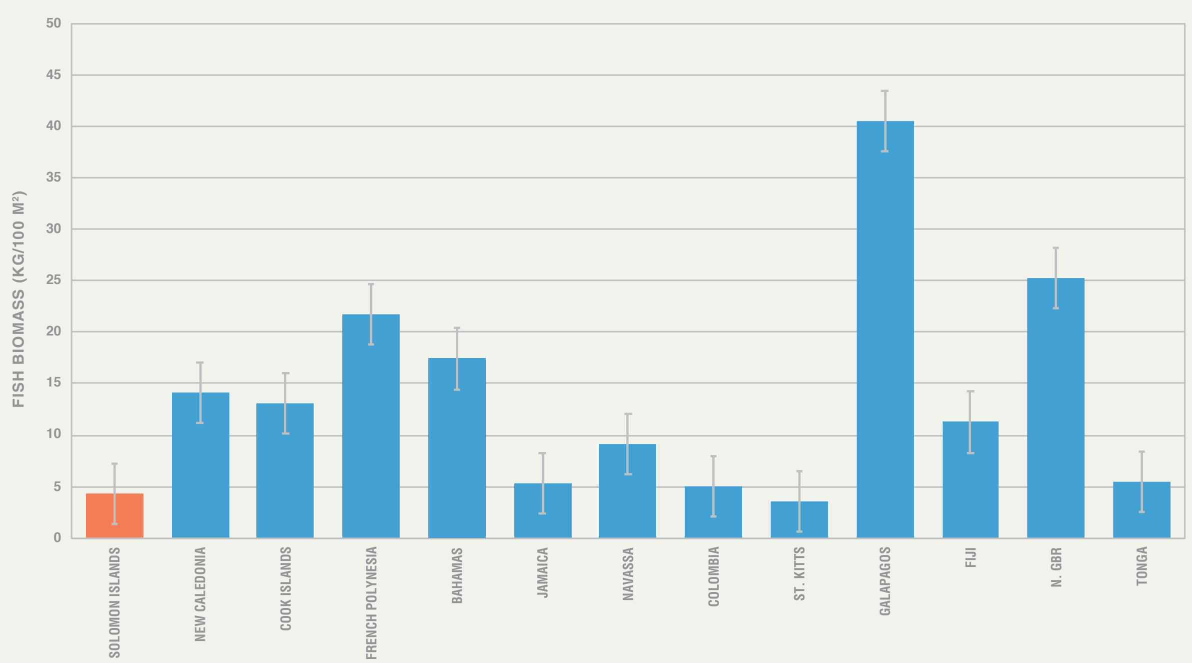
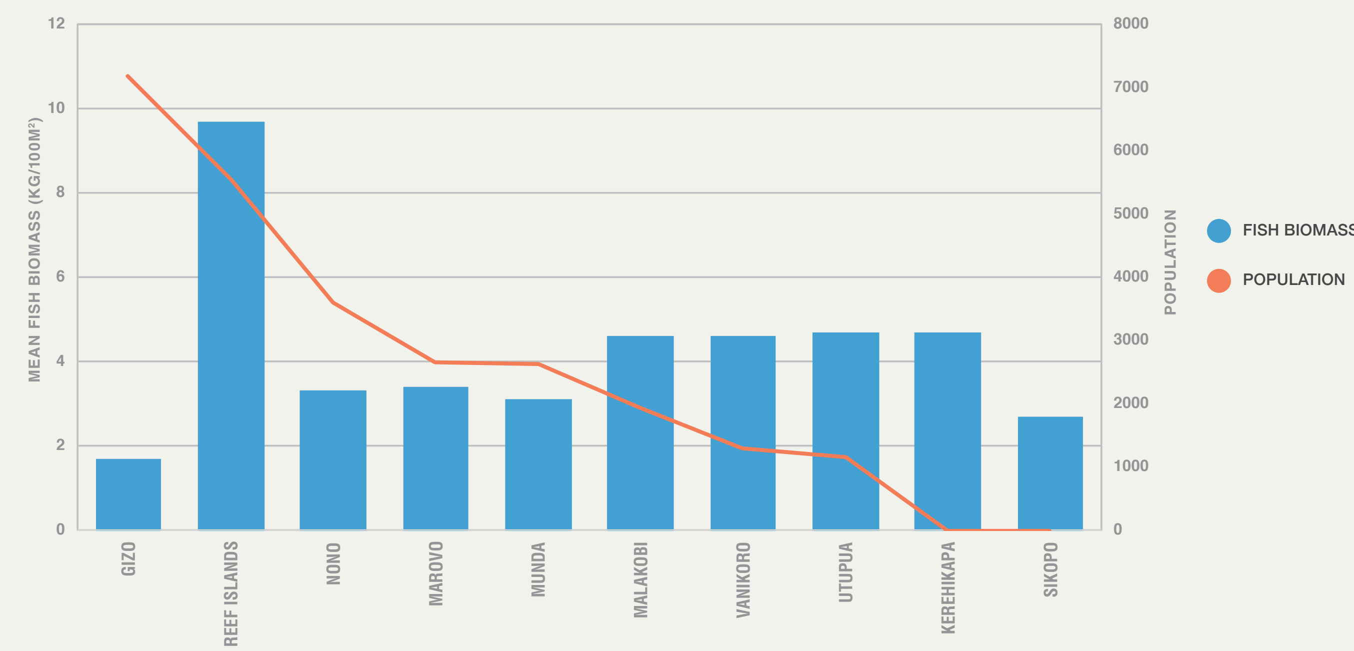


Figure 24 COMPARISON OF HUMAN POPULATION AGAINST MEAN FISH BIOMASS (KG/100M^2) FOR EACH LOCATION.



The Temotu province is the most remote and least populous region surveyed in the Solomon Islands. Both the benthic and fish communities reflect the lower anthropogenic pressures as there was both higher coral cover, and a more diverse fish community. Throughout the Temotu province, the depth gradient in the benthic communities was distinctive. In the shallower waters (<10 m), live coral cover reached nearly 60% in some areas which is high when compared to the regional average. In depths deeper than 10-15 meters, there were large mats of *Halimeda* that can be abrasive and wash away coral larvae that settle nearby, overall reducing the coral growth and cover. This large presence of *Halimeda* may indicate an influx of nutrients to the area, possibly by localized upwelling. A number of factors including light attenuation, herbivory, and thermoclines or haloclines could contribute to *Halimeda* being limited to the deeper sites, however, this should be studied further.

In general, fish populations on the reefs of the Solomon Islands were diverse and abundant. However, overall fish biomass was low relative to the number of fish, and small fish heavily dominated at most sites. When compared to other sites surveyed on the GRE, the Solomon Islands had some of the lowest fish biomass recorded **(Figure 23)**. This pattern indicates that the Solomon Islands' fish populations are generally characterized by many dense populations of small fish across all trophic categories. This pattern is most apparent at Sikopo, which had mean fish densities comparable with many other sites, but much lower mean biomass and fewer large (41-50 cm) fish relative to other sites.

Two notable exceptions to this pattern were the Reef Islands and Tinakula, which had high fish density and high biomass, particularly in the highest trophic category. Tinakula, in particular, had fewer small fish, as well as fewer fish in the lower trophic categories, than the rest of the sites. This is likely due to the recent volcanic eruptions and essentially bare substrate on one side of the island. The Reef Islands fish populations had the highest mean species richness, fish density, and biomass of all of the sites. However, it is important to note that sampling intensity was highest in this area which may have influenced the dominance of some metrics.

Gizo is the capital and second-most populous area in the Western province. The local communities have developed the Gizo Environmental Livelihood and Conservation Association (GELCA) which locally manages fishing pressure on the reef fish communities[13]. The area around Gizo had moderate coral cover, varying based on location within the reef system. However, the fish populations at Gizo had the lowest mean value for all metrics and the highest proportion of small fish **(Figure 24)**. This pattern is likely due to localized higher fishing pressure. These findings are consistent with those of Aswani and Sabetian (2010), who noted that fishing pressure in Gizo was high due to the population density in the area, and that, in the case of parrotfish, most of the pressure was focused on fish in large and mid-size categories[43]. This study showed that the breakdown of traditional governance of the reefs in Gizo has led to the decline of parrotfish populations, and the data presented in this report indicate that the same may be true for all fish species at this site.

5.0 CONSERVATION RECOMMENDATIONS

5.0

Marine conservation and fisheries management in the Solomon Islands can be difficult as communities heavily rely on the nearshore ecosystems for sustenance and income generation. Regardless, communities also have the responsibility to protect and manage their coastal and marine environment that are within their customary marine tenure. Many communities have engaged in marine resource management and conservation initiatives in their coastal environment; however, most are very small and protect small areas, totaling less than 1,000 km^2 nationally. The majority of these locally managed marine areas (LMMAs) and MPAs are focused around Choiseul, Western, Isabel, Central, Malaita, and Guadalcanal Province. Many of these LMMAs were supported by the National Government and NGOs such as The Nature Conservancy and World Wildlife Fund, among others, working closely with local communities to ensure protection and sustainable utilization of marine resources. To be effective, it is imperative to have governmental and NGOs support, but perhaps more importantly, support and compliance from the local communities to ensure resources are protected or utilized on a sustainable level (Figure 25).

Fisheries regulations need to be implemented to support the **longevity of the reefs** and **fish populations.**

As seen in the results from the GRE, the fish communities of the Solomon Islands are being overexploited and fisheries regulations need to be implemented to support the longevity of the reefs, and in particular, the fish populations. The majority of the MPAs and LMMAs in the Solomon Islands do not have strict if any, fishing regulations, and those that do, do not appear to be working[44]. Highly populated areas such as around Gizo and Munda should continue to work toward a fishing-management plan that includes number and catch size limitations, as well as closing fishing to some areas to allow larger fish important to sustenance to regenerate.

By removing too many large fish, the communities are, in the long run, risking overexploitation and possibly permanently damaging both the benthic community and fish populations.

Evidence of Crown-of-Thorn Starfish (COTS) outbreaks were observed near Munda and the Reef Islands. In the Reef Islands, KSLOF scientists removed 182 of these predatory starfish in an effort to thwart further damage to the reef. Depending on the severity of the outbreak, COTS can decimate an entire reef system by essentially killing and consuming all live coral present. This destruction can have long term effects on the stability of the reef ecosystem and can affect not only the live coral but the fish populations as well. In most cases, people frequenting the reef are the most likely to observe an outbreak through an increased number of COTS scars (white, dead corals), being present. These can easily be differentiated by bleaching as the scars will be more isolated on the reef. KSLOF has developed a COTS removal plan that can be found on the Foundation's website at lof.org. This plan was originally designed for the Cook Islands, but it can be applied to any reef system. Increasing education about the signs and symptoms of a COTS outbreak will be the most important way to prevent a major outbreak and conserve the reef effectively from this disturbance.

Another major concern was the notable logging and mining occurring nearshore. Deforestation through logging and mining can be detrimental to the reefs as they destabilize the land sediments and cause them to run off onto the nearshore marine ecosystems. This sedimentation impacts the benthic and fish communities, as well as mangroves and seagrasses, decreasing the overall productivity of these vital ecosystems. While continuing these practices is not recommended, there are ways to mitigate the runoff and reduce sedimentation on nearshore ecosystems. The government of the Solomon Islands should strictly set and enforce regulations requiring mining and logging companies to use best industry practices to reduce runoff, including implementing buffer strips, carefully planning roads and skid trails for hauling out the resources to reduce environmental damage, and land recovery once the logging and mining have ceased. This will benefit not only reef communities but mangrove and seagrass habitats as well. Besides the environmental importance, seagrasses and mangroves benefit local community members as they can act as a barrier to storm surge and wave action caused by storms or tsunamis.

There are many global changes impacting coral reefs, making local conservation efforts a priority. Global overexploitation of the worlds fish populations, widespread coral bleaching, increased storm activity and severity, and widespread pollution are just a few of the threats coral reefs are facing. Local conservation and management practices help protect coral reefs and buffer them against the more global threats which are harder to mitigate on a large scale. Prioritizing local management and taking steps now to protect the reef, reduce fishing pressure, improving water quality, and limiting the impact of COTS outbreaks can improve the resiliency of individual reefs facing the global coral reef crisis.

The Khaled bin Sultan Living Oceans Foundation hopes the information and recommendations provided in this report will help guide the local communities to better preserve their reef ecosystems for generations to come.

Figure 25 LOCALLY MANAGED MARINE AREAS AND MAPS CAN HELP COMMUNITIES ENSURE PROTECTION AND SUSTAINABLE UTILIZATION OF THEIR MARINE RESOURCES. THIS PHOTO WAS TAKEN IN THE ARNAVON COMMUNITY MARINE CONSERVATION AREA NEAR SIKOPO AND HIGHLIGHTS A REEF THAT HAS HIGH BENTHIC AND FISH DIVERSITY.

ACKNOWLEDGMENTS

The Global Reef Expedition research mission to the Solomon Islands would not have been possible without the leadership, vision, and generosity of His Royal Highness Prince Khaled bin Sultan. We are deeply appreciative of his financial support and for the generous use of his research vessel, the M/Y Golden Shadow.

The Khaled bin Sultan Living Oceans Foundation is grateful for the assistance provided by our partners in the Solomon Islands in obtaining the permits for research and getting permission to work within each of the provinces surveyed. We would like to express our thanks to the Solomon Island Ministry of Environment, Climate Change, Disaster Management, and Meteorology, Western Provincial Government, Isabel Provincial Secretary, and Temotu Provincial Government for granting us permission to sample and study the reefs of your country. KSLOF would like to especially thank Ivory Akao of the Ministry of Marine Resources for her expertise and hard work in assisting with the execution of this research mission.

This research mission to the Solomon Islands would not have been possible without the leadership, vision, and generosity of His Royal Highness Prince Khaled bin Sultan. We are deeply appreciative of his financial support and for the generous use of his research vessel, the M/Y *Golden Shadow*. His vision of *Science Without Borders®* was materialized in this research mission through the involvement of scientists from the following countries: Solomon Islands, United States, Portugal, Australia, the Philippines, and Taiwan.

The Khaled bin Sultan Living Oceans Foundation appreciates the skill and dedication of the scientific divers who aided in the collection of vital data for the Foundation, especially our international partners from Nova Southeastern University, University of the Philippines, University of the Azores, University of Miami, NOAA, University of Queensland, James Cook University, University of the Azores, Ocean Watch, Hawaii Institute of Marine Biology, Underwater Earth, and the National Museum of Marine Biology and Aquarium, Taiwan. The Foundation is particularly grateful for the dedicated efforts of each scientist and would like to thank each of you for your contributions, especially the detailed data you gathered.

The Global Reef Expedition research mission to the Solomon Islands benefited from Captain Steve Breen and the officers and crew of the M/Y *Golden Shadow*. They were responsible for getting us safely to our research sites and conducting all logistical operations of the dive and research vessels. They ensured that each researcher had access to the study sites and proper working tools and equipment needed to complete the work and had highly capable engineers and electricians that repaired and fabricated gear when we ran into complications. Behind the scenes, the crew worked at all hours to support the scientists on the Global Reef Expedition, and for that, we are immensely grateful.

As deliverables from this research project are completed, we look forward to continuing these partnerships to ensure the information and data from this project are applied toward the conservation needs and goals of the people of the Solomon Islands.

Thank you to Prince Khaled Bin Sultan, the government and communities of the Solomon Islands, esteemed scientists, and crew of the M/Y *Golden Shadow* for making this research mission a success!

LITERATURE CITED

1. Veron, J. E. N. et al. Delineating the Coral Triangle. *Galaxea, Journal of Coral Reef Studies* **11**, 91–100 (2009).
2. *State of the Coral Triangle: Solomon Islands*. vol. 4 (Asian Development Bank, 2014).
3. Grant, K. L. & Miller, M. L. A cultural consensus analysis of marine ecological knowledge in the Solomon Islands. *SPC Traditional Marine Resource Management and Knowledge Information Bulletin* **17**, 11 (2004).
4. Albert, J. A., Trinidad, A., Boso, D. & Schwartz, A. J. *Coral reef economic valuation and incentives for coral farming in Solomon Islands*. (2012).
5. Porter, D. & Allen, M. The Political Economy of the Transition from Logging to Mining in Solomon Islands. *State, Society, and Governance in Melanesia* **12**, (2015).
6. Halpern, B. et al. Marine Protected Areas and Resilience to Sedimentation in the Solomon Islands. *Coral Reefs* **32**, 61–69 (2013).
7. Albert, S., Grinham, A., Gibbes, B., Tibbetts, I. & Udy, J. Indicators of coral reef ecosystem recovery following reduction in logging and implementation of community-based management schemes in the Solomon Islands. *Pac. Conserv. Biol.* **20**, 75 (2014).
8. Aswani, S. & Hamilton, R. J. Integrating indigenous ecological knowledge and customary sea tenure with marine and social science for conservation of bumphead parrotfish (*Bolbometopon muricatum*) in the Roviana Lagoon, Solomon Islands. *Environmental Conservation* **31**, 69–83 (2004).
9. Goetze, J. S. et al. Drivers of reef shark abundance and biomass in the Solomon Islands. *PLoS ONE* **13**, e0200960 (2018).
10. Aswani, S. Patterns of marine harvest effort in southwestern New Georgia, Solomon Islands: resource management or optimal foraging? *Coastal Management* **40**, 207–235 (1998).
11. Foale, S., Wini, L. & Fernandes, L. *The Arnavon Community Marine Conservation Area: a review of successes, challenges and lessons learned*. (2017).
12. United Nations Development Programme. *Arnavon Community Marine Conservation Area Management Committee, Solomon Islands*. (2012).
13. Liligeto, W. *Gizo Environment Livelihood Conservation Association (GELCA) Resource Management Plan*. (2013).
14. UNEP-WCMC. *The World Database on Protected Areas (WDPA) statistics*. (2017).
15. Purkis, S. J. et al. High-resolution habitat and bathymetry maps for 65,000 sq. km of Earth's remotest coral reefs. *Coral Reefs* **38**, 467–488 (2019).
16. Kerr, J. & Purkis, S. An algorithm for optically-deriving water depth from multispectral imagery in coral reef landscapes in the absence of ground-truth data. *Remote Sensing of Environment* **210**, 307–324 (2018).
17. Kohler, K. E. & Gill, S. M. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers and Geosciences* **32**, 1259–1269 (2006).
18. Komyakova, V., Munday, P. L. & Jones, G. P. Relative Importance of Coral Cover, Habitat Complexity and Diversity in Determining the Structure of Reef Fish Communities. *PLoS ONE* **8**, e83178 (2013).
19. English, S., Wilkinson, C. & Baker, V. S*urvey Manual for Tropical Marine Resources*. (Australian Institute of Marine Science, 1997).
20. Bacchet, P., Zysman, T. & Lefevre, Y. *Guide Des Poissons De Tahiti Et Ses Isles*. (Pirae, 2006).
21. Kuiter, R. H. & Debelius, H. *World Atlas of Marine Fishes*. (IKAN-Unterwasserarchiv, 2007).
22. Randall, J. E. *Reef and Shore Fishes of the South Pacific, New Caledonia to Tahiti and Pitcairn Islands*. (University of Hawaii Press, 2005).
23. Allen, G. R., Steene, R., Humann, P. & Deloach, N. *Reef Fish Identification Guide - Tropical Pacific*. (New World Publications, Inc., 2012).
24. Letourneur, Y. Length-weight relationship of some marine fish species in Reunion Island, Indian Ocean. *Naga* **21**, 37–38 (1998).
25. Letourneur, Y., Kulbicki, M. & Labrosse, P. Length-weight relationship of fishes from coral reefs and lagoons of New Caledonia: an update. *Naga* **21**, 39–46 (1998).
26. Gonzales, B. J., Palla, H. P. & Mishina, H. Length-weight relationship of five serranids from Palawan Island, Philippines. *Naga, the ICLARM Quarterly* **23**, 26–28 (2000).
27. FishBase. A Global Information System on Fishes. *Fishbase* http://www.fishbase.org/home.htm (2004).
28. Kulbicki, M., Mou Tham, G., Thallot, P. & Wantiez, L. Length-weight relationships of fish from the lagoon of New Caledonia. *Naga, The ICLARM Quarterly* **16**, 26–30 (1993).
29. Bozec, Y.-M., Kulbicki, M., Chassot, E. & Gascuel, D. Trophic signature of coral reef fish assemblages: Towards a potential indicator of ecosystem disturbance. *Aquatic Living Resources* **18**, 103–109 (2005).
30. Simon, A. N. P., Sabban, F. B., Chipeco, C. B. & Ticzon, V. S. *Trophic spectrum analysis of reef fishes in Twin Rocks Marine Sanctuary, Northern Verde Island Passage, Philippines*. (2016).
31. Robinson, J. P. W., Baum, J. K. & Giacomini, H. Trophic roles determine coral reef fish community size structure. *Canadian Journal of Fisheries and Aquatic Sciences* **73**, 496–505 (2016).
32. Crosby, M. P. & Reese, E. *A manual for monitoring coral reefs with indicator species: butterflyfishes as indicators of change on Indo-Pacific reefs*. (Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, 1996).
33. Mumby, P. J. et al. Fishing, Trophic Cascades, and the Process of Grazing on Coral Reefs. *Science* **311**, 98–101 (2006).
34. Honda, K., Nakamura, Y., Nakaoka, M., Uy, W. H. & Fortes, M. D. Habitat Use by Fishes in Coral Reefs, Seagrass Beds and Mangrove Habitats in the Philippines. *PLoS ONE* **8**, e65735 (2013).
35. Mumby, P. J. et al. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. *Nature* **427**, 533–536 (2004).
36. Jones, G. P., McCormick, M. I., Srinivasan, M. & Eagle, J. V. Coral decline threatens fish biodiversity in marine reserves. *Proceedings of the National Academy of Sciences* **101**, 8251–8253 (2004).
37. Diaz-Pulido, G., Harii, S., McCook, L. J. & Hoegh-Guldberg, O. The impact of benthic algae on the settlement of a reef-building coral. *Coral Reefs* **29**, 203–208 (2010).
38. Price, N. Habitat selection, facilitation, and biotic settlement cues affect distribution and performance of coral recruits in French Polynesia. *Oecologia* **163**, 747–758 (2010).
39. Brodie, J., Fabricius, K., De'ath, G. & Okaji, K. Are increased nutrient inputs responsible for more outbreaks of crown-of-thorns starfish? An appraisal of the evidence. *Marine Pollution Bulletin* **51**, 266–278 (2005).
40. *Oceanography and Marine Biology An Annual Review V54*. (CRC Press, 2016). doi:10.1201/9781315368597
41. Ramohia, P. Fisheries Resources: Commercially Important Macroinvertebrates. in *Solomon Islands Marine Assessment: Technical Report of Survey Conducted during 13 May to 17 June 2004* (eds. Green, A. et al.) (2006).
42. Lipsett-Moore, G. et al. *Ridges to Reefs Conservation Plan for Choiseul Province, Solomon Islands*. 53 (2010).
43. Aswani, S. & Sabetian, A. Implications of Urbanization for Artisanal Parrotfish Fisheries in the Western Solomon Islands. *Conservation Biology* **24**, 520–530 (2010).
44. Hamilton, R. J., Hughes, A., Brown, C. J., Leve, T. & Kama, W. Community-based management fails to halt declines of bumphead parrotfish and humphead wrasse in Roviana Lagoon, Solomon Islands. *Coral Reefs* **38**, 455–465 (2019).

APPENDIX 1 | DIVE SITES AND SITE DESCRIPTIONS

Islands	Site	Date	Longitude	Latitude	Reef Location	Reef Type
Munda	Site 01	10/29/14	157.223	-8.385	forereef	fringing reef
Munda	Site 02	10/29/14	157.212	-8.350	forereef	fringing reef
Munda	Site 03	10/29/14	157.224	-8.351	forereef	back reef
Gizo	Site 04	10/30/14	156.821	-8.160	forereef	barrier reef
Gizo	Site 05	10/30/14	156.896	-8.157	forereef	barrier reef
Gizo	Site 06	10/30/14	156.862	-8.127	backreef	fringing reef
Gizo	Site 07	10/31/14	156.770	-8.087	forereef	fringing reef
Gizo	Site 08	10/31/14	156.798	-8.101	lagoon	fringing reef
Gizo	Site 09	10/31/14	156.886	-8.114	lagoon	back reef
Kerehikapa	Site 10	11/1/14	158.053	-7.496	lagoon	barrier reef
Kerehikapa	Site 11	11/1/14	158.047	-7.483	lagoon	fringing reef
Kerehikapa	Site 12	11/1/14	158.021	-7.448	lagoon	fringing reef
Sikopo	Site 13	11/2/14	158.000	-7.461	lagoon	channel
Sikopo	Site 14	11/2/14	158.001	-7.467	lagoon	channel
Sikopo	Site 15	11/2/14	157.962	-7.430	lagoon	fringing reef
Malakobi	Site 16	11/3/14	158.044	-7.304	lagoon	barrier reef
Malakobi	Site 17	11/3/14	158.156	-7.406	forereef	fringing reef
Malakobi	Site 18	11/3/14	158.198	-7.365	forereef	barrier reef
Malakobi	Site 19	11/4/14	158.020	-7.335	lagoon	back reef
Malakobi	Site 20	11/4/14	158.054	-7.348	channel	back reef
Malakobi	Site 21	11/4/14	158.076	-7.350	lagoon	back reef
Nono	Site 22	11/5/14	157.787	-8.772	forereef	patch reef
Nono	Site 23	11/5/14	157.839	-8.735	channel	patch reef
Nono	Site 24	11/5/14	157.809	-8.823	forereef	patch reef
Nono	Site 25	11/6/14	157.805	-8.675	forereef	patch reef
Nono	Site 26	11/6/14	157.766	-8.773	forereef	patch reef
Nono	Site 27	11/6/14	158.093	-8.747	lagoon	patch reef
Marovo	Site 28	11/7/14	157.917	-8.407	forereef	fringing reef
Marovo	Site 29	11/7/14	157.982	-8.433	lagoon	fringing reef
Nono	Site 30	11/7/14	157.793	-8.644	forereef	patch reef
Utupua	Site 32	11/10/14	166.448	-11.282	forereef	barrier reef
Utupua	Site 33	11/10/14	166.466	-11.297	forereef	patch reef
Utupua	Site 34	11/11/14	166.445	-11.265	forereef	barrier reef
Utupua	Site 35	11/11/14	166.533	-11.188	channel	barrier reef
Utupua	Site 36	11/11/14	166.472	-11.210	back reef	barrier reef
Utupua	Site 37	11/12/14	166.452	-11.240	forereef	barrier reef

Islands	Site	Date	Longitude	Latitude	Reef Location	Reef Type
Utupua	Site 38	11/12/14	166.599	-11.228	back reef	barrier reef
Utupua	Site 39	11/12/14	166.521	-11.331	forereef	patch reef
Utupua	Site 40	11/13/14	166.596	-11.290	back reef	barrier reef
Utupua	Site 41	11/13/14	166.475	-11.304	back reef	patch reef
Utupua	Site 42	11/13/14	166.462	-11.306	forereef	channel
Vanikoro	Site 43	11/14/14	166.953	-11.586	forereef	barrier reef
Vanikoro	Site 44	11/14/14	166.941	-11.578	forereef	barrier reef
Vanikoro	Site 45	11/14/14	166.912	-11.584	forereef	barrier reef
Vanikoro	Site 46	11/15/14	167.001	-11.573	forereef	barrier reef
Vanikoro	Site 47	11/15/14	166.946	-11.595	lagoon	patch reef
Vanikoro	Site 48	11/15/14	166.868	-11.564	forereef	barrier reef
Vanikoro	Site 49	11/16/14	166.785	-11.615	lagoon	patch reef
Vanikoro	Site 50	11/16/14	166.809	-11.585	lagoon	patch reef
Vanikoro	Site 51	11/16/14	166.827	-11.563	forereef	barrier reef
Reef Islands	Site 52	11/17/14	166.147	-10.284	forereef	barrier reef
Reef Islands	Site 53	11/17/14	166.295	-10.294	lagoon	patch reef
Reef Islands	Site 54	11/17/14	166.127	-10.283	forereef	barrier reef
Reef Islands	Site 55	11/18/14	166.369	-10.264	channel	fringing reef
Reef Islands	Site 56	11/18/14	166.333	-10.258	forereef	fringing reef
Reef Islands	Site 57	11/18/14	166.345	-10.315	forereef	fringing reef
Reef Islands	Site 58	11/19/14	166.227	-10.184	forereef	barrier reef
Reef Islands	Site 59	11/19/14	166.111	-10.197	forereef	barrier reef
Reef Islands	Site 60	11/19/14	166.271	-10.284	channel	barrier reef
Reef Islands	Site 61	11/20/14	166.192	-10.194	forereef	barrier reef
Reef Islands	Site 62	11/20/14	166.072	-10.217	forereef	barrier reef
Reef Islands	Site 63	11/20/14	166.227	-10.286	channel	barrier reef
Reef Islands	Site 64	11/21/14	166.248	-10.164	forereef	fringing reef
Reef Islands	Site 65	11/21/14	166.198	-10.152	forereef	fringing reef
Reef Islands	Site 66	11/21/14	166.250	-10.255	lagoon	barrier reef
Tinakula	Site 67	11/22/14	165.813	-10.373	forereef	fringing reef
Tinakula	Site 68	11/22/14	165.790	-10.397	forereef	fringing reef
Tinakula	Site 69	11/22/14	165.794	-10.376	forereef	fringing reef

APPENDIX 2 | PARTICIPANT LIST

Participant	Institution	Function
Andrew Bruckner, Ph.D.	Living Oceans Foundation (KSLOF)	Former Chief Scientist, coral assessments
Alex Dempsey, M.S.	Living Oceans Foundation	Director of Science Management
Amy Heemsoth	Living Oceans Foundation	Director of Education
Renée Carlton	Living Oceans Foundation, formerly University of Miami/NOAA	Marine Ecologist, ocean acidification researcher
Ivory Akao	Ministry of Fisheries and Marine Resources	Coordination
Steve Saul, Ph.D.	Nova Southeastern University (NCRI)	KSLOF Post Doc Fellow, habitat mapping
Robert Gardiner	Nova Southeastern University (NCRI)	Ph.D. candidate, habitat mapping
Grace Frank	James Cook University	Coral assessments
Ken Marks	Atlantic and Gulf Rapid Reef Assessment	Coral reef phototransects
Badi Samaniego	University of Philippines	KSLOF Fellow, fish surveys
Joao Monteiro, Ph.D.	University of Azores	KSLOF Fellow, coral symbionts
Anderson Mayfield, Ph.D.	National Museum of Marine Biology and Aquarium, Taiwan	KSLOF Fellow, Post Doc, coral health
Kristin Stolberg	University of Queensland	Benthic assessments
Stefan Andrews	Rolex Fellow	Reef fish surveys
Georgia Coward	OceansWatch	Coral reef education
Garrett Johnson	Hawaii Institute of Marine Biology	Fish assessments
Kristen Brown	Underwater Earth	Catlin Seaview team
Peter Dalton	Underwater Earth	Catlin Seaview team
Ulricke Siebick	Underwater Earth	Catlin Seaview team
Benjamin Neal	Underwater Earth	Catlin Seaview team
Wade Fairley	Ministry of Fisheries and Marine Resources	Underwater/topside video

NOTES

NOTES

Khaled bin Sultan
Living Oceans
Foundation

ISBN: 978-0-9975451-6-6