VOL 10

NEW CALEDONIA

GLOBAL REEF EXPEDITION FINAL REPORT

Khaled bin Sultan Living Oceans Foundation

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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.

This final report is submitted to fulfill the requirements of the Final Report for the Global Reef Expedition: New Caledonia Research Mission. This is in accordance with the research permit approved by *Le Haut-Commissaire de la Republique en Nouvelle-Caledonia Ref. 157/CMRT,* issued October 9, 2013; *Le Gouvernement de la Nouvelle-Caledonie, No. 2013-2733/GNC,* issued October 1, 2013 and *No. 2013-3329/GNC,* issued November 26, 2013; and *Presidence, Secretariat General de la Province Sud, No. 2421-2013/ARR/DENV,* issued November 6, 2013. The North Province granted authorization to conduct research on Cook Reef through IRD.

Khaled bin Sultan Living Oceans Foundation (KSLOF) was incorporated in California as a 501(c)(3), public benefit, private operating foundation in September 2000. The Living Oceans Foundation is dedicated to providing science-based solutions to protect and restore ocean health.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Khaled bin Sultan Living Oceans Foundation (KSLOF) was graciously funded by His Royal Highness Prince Khaled bin Sultan to protect and preserve coral reefs around the world. Prince Khaled envisioned a foundation that utilizes science, education, and outreach — all working together — to expand coral reef conservation efforts on a global scale. To fulfill the Foundation's mission, KSLOF devised a plan to complete a comprehensive global survey of coral reefs globally, culminating as the Global Reef Expedition (GRE). This expedition enabled scientists from around the world to conduct applied research on coral reefs in order to provide valuable information and tools needed to develop regional and global conservation measures.

The GRE mission to New Caledonia was one of the most rigorous surveying efforts undertaken by the Foundation. This major surveying effort allows KSLOF to provide a comprehensive analysis of the benthic habitats, benthic substrate, and fish communities of the Entrecasteaux Atolls, Cook Reef, Prony Bay, and Ile des Pins.

The reefs of New Caledonia are some of the most beautiful and well-preserved habitats in the world. With the designation of *Le Parc Naturel de la Mer de Corail* in April 2014, the data collected by KSLOF and New Caledonia's prestigious scientists will be highly beneficial to the continued monitoring and management efforts for this park. KSLOF felt it was important to survey the reefs of New Caledonia to not only aid in the conservation of these reefs, but also to contribute vital data to the Foundation's global coral reef conservation efforts.

> While the conservation efforts of New Caledonia are **some of the most advanced in the South Pacific,** we hope the data presented in this report will shed light on areas that need attention and more robust management.

The GRE mission to New Caledonia was specifically chosen to develop high-resolution habitat maps and conduct surveys to better understand the unique reef habitats found there. From October to November 2013, scientists from KSLOF worked in close collaboration with expert researchers from the *Institut de Recherche pour le Développment (IRD)*, as well as experts from around the world to document and map coral reef habitats and fish communities of the Entrecasteaux Atolls, Cook Reef, Ile des Pins, and Prony Bay. The research in New Caledonia was conducted with the following objectives:

1. **Identify and characterize shallow marine habitats and develop habitat and bathymetric maps;**
2. **Evaluate the composition, structure, and health of coral reefs using standardized assessment protocol;**
3. **Assess the diversity, abundance, and population structure of fishes, corals, and other invertebrates and algae, including commercially valuable species.**

Experts conducted 554 benthic habitat transects and 504 fish surveys and mapped over 2,600 km^2 of coral reefs and surrounding shallow-water marine habitats at 10 locations throughout New Caledonia. The 74 dive sites selected on the Global Reef Expedition to New Caledonia included remote habitats, as well as sites close to human population centers.

HABITAT MAPPING

High-resolution habitat and bathymetric maps were created for the 10 locations surveyed in New Caledonia. These maps have a spatial resolution of 2 m x 2 m. The habitat classifications in the maps clearly describe the substrate and reef habitats found in these diverse locations. The maps and data derived from them will be beneficial for marine spatial planning and are available on our website at www.lof.org/maps. We encourage the public, scientists, and policy makers to consult these maps, particularly those interested in marine management, to better understand the areas that might require protection.

BENTHIC COVER ASSESSMENTS

To assess the benthic communities of the reefs of New Caledonia, KSLOF scientists used standardized survey methods and photographic assessments to measure live coral cover, algal communities, and coral diversity. The surveys revealed some unexpected findings that were both intriguing and exciting. As expected, the Entrecasteaux Atolls and Cook Reef — which were the most remote reefs surveyed in New Caledonia — boasted some of the highest live coral cover observed. Ile des Pins, however, had the lowest. This may be due to the close proximity to human population centers found on the island. The most surprising finding was the unusually high percentage of live coral cover found at Prony Bay. This location had some of the highest live coral cover ever observed on the Global Reef Expedition. Given the amount of nutrient and sediment runoff found in Prony Bay from the nearby copper mines, this finding was unexpected. Further studies into the resilience of these corals and the benthic community in Prony Bay might shed light on the adaptability of corals in high-stress environments.

FISH COMMUNITY ASSESSMENT

The fish communities of New Caledonia were analyzed by grouping fish into trophic levels and size classes, and these findings were compared among the different dive sites surveyed. Similar to the benthic communities, the Entrecasteaux Atolls and Cook Reef housed some of the highest fish biomass, diversity, and mean species richness found in New Caledonia. This is likely related to lower fishing pressure, due to their remote locations. Conversely, Prony Bay and Ile des Pins had low fish diversity, biomass, and species richness, which can likely be attributed to the higher fishing pressures experienced at these sites.

CONSERVATION RECOMMENDATIONS

While the conservation efforts of New Caledonia are some of the most advanced in the South Pacific, we hope the data presented in this report will shed light on areas that need attention and more robust management. It is evident that the nearshore fisheries are being directly impacted by the local communities found on Grande Terre and Ile des, and increased protection efforts seem necessary. By addressing the high fishing pressure, not only will the fish populations become more diverse and improve in overall biomass, there will likely be an increase in the live coral cover as a result. An implementation of size limits and/or catch limits, applied to the New Caledonian Exclusive Economic Zone (EEZ) through improved legislation and enforcement, particularly of the commercially important species, could lead to more large, predatory fish. Areas reliant on sustenance fishing will benefit greatly from these harsher fishing regulations and the implementation of no-take or no-entry Marine Protected Areas, as they will allow for better management of the reef fish, particularly if applied around Ile des Pins. KSLOF commends New Caledonia on its conservation efforts and hopes it uses the recommendations provided in this report to continue to improve its management practices in the region. We believe that with continued and improved management practices, coral reefs throughout New Caledonia will be able to thrive.

INTRODUCTION

1.0

The world has recognized the reefs of New Caledonia as hosting some of the most beautiful and well-preserved tropical marine habitats, globally[1,2]. New Caledonia is isolated in the southwest Pacific Ocean, about 1,300 km east of Australia[3]. The country is situated in the Coral Sea, which hosts some of the most biodiverse coral reefs in the world[4]. In July 2008, UNESCO declared the Entrecasteaux Atolls, as well as the lagoon surrounding Grande Terre, and four other marine sites, as official World Heritage Sites[5,6] with the goal of preserving and protecting New Caledonia's coral reef habitats. This designation prompted the local government to expand protection of their marine habitats to the entire Exclusive Economic Zone (EEZ).[5] Their vision was to create an expansive marine park allowing New Caledonia to more efficiently manage their marine resources. On September 4, 2012, the government of New Caledonia announced its plan to develop a "natural park" encompassing the entire EEZ with the intention of protecting all its natural waters and habitats. *Le Parc Naturel de la Mer de Corail* was adopted into law on April 23, 2014, protecting 1.3 million km^2, making it one of the largest marine protected areas in the world[5]. This commitment toward conservation aligned strongly with the conservation mission of the Khaled bin Sultan Living Oceans Foundation (KSLOF), prompting our collaboration with New Caledonia on the Global Reef Expedition (GRE).

New Caledonia benefits from a unique jurisdiction compared with the other French overseas collectivities and territories, with a large political autonomy. France, the local government, and three provinces (North, South, and Loyalty Island) share different responsibilities and competences in a complex legal framework. Traditional customary Kanak rules also play a strong role in many local decisions, especially regarding natural resources.

The Living Oceans Foundation felt it was important to survey the reefs of New Caledonia to not only aid these three jurisdictions in the conservation of these beautiful reefs, but to also collect vital data that will contribute to the Foundation's conservation efforts globally. From October to November 2013, the KSLOF GRE surveyed atolls and reefs to the north and south of Grande Terre, New Caledonia (Figure 1). KSLOF embarked on the mission to New Caledonia with the goal of developing high-resolution habitat maps to aid in conservation efforts, and to better understand the reef habitats of this unique environment. On this expedition, KSLOF worked in partnership with the *Institut de Recherche pour le Développment (IRD)* and researchers from around the world to document and map the reef habitats and fish communities of the Entrecasteaux Atolls, Cook Reef, Ile des Pins, and Prony Bay. The research in New Caledonia was conducted with the following objectives:

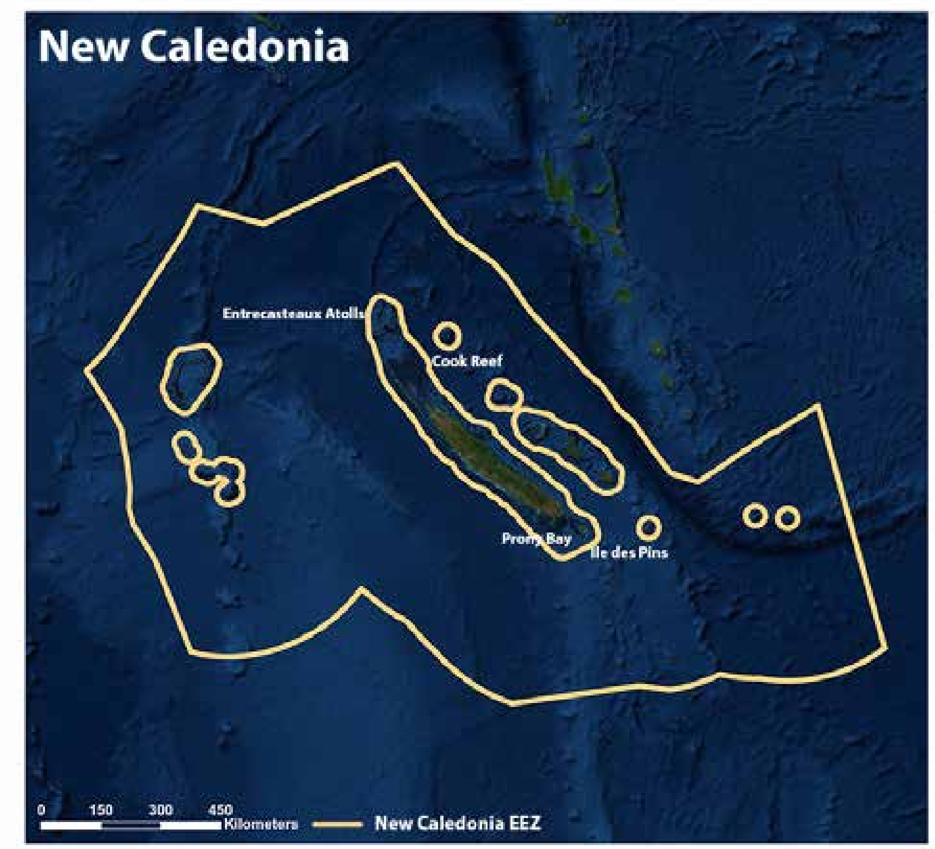
1. **Identify and characterize shallow marine habitats and develop habitat and bathymetric maps;**
2. **Evaluate the composition, structure, and health of coral reefs using standardized assessment protocol;**
3. **Assess the diversity, abundance, and population structure of fishes, corals, and other invertebrates and algae, including commercially valuable species.**

All the sites surveyed on the GRE mission to New Caledonia were specifically chosen because they were, at the time of the expedition in 2013, priority sites for conservation and required additional scientific knowledge. Most of the research sites selected were also remote and hard to access, especially in the north, so the GRE would fill several important research gaps.

All of the sites surveyed on the GRE mission to New Caledonia were **specifically chosen** because they were identified **as priority sites for conservation.**

The information collected on the GRE will help fill these gaps in knowledge of the marine habitats surrounding the reefs of the north and south of Grande Terre. The data provided in this report will also complement ongoing local monitoring activities and research programs, since currently there is no standardized sampling protocol among the different sampling stations. Also, specific information collected during the GRE or generated after the campaign (e.g., coral diseases, habitat maps) remains rare for New Caledonia[7]. With the use of the *M/Y Golden Shadow* research vessel, KSLOF and visiting scientists from New Caledonia conducted a thorough study of these remote locations. The Khaled bin Sultan Living Oceans Foundation hopes the valuable information collected on this expedition will aid in the management and protection of nearshore marine fisheries and marine habitats in New Caledonia.

Figure 1 MAP SHOWING THE EXCLUSIVE ECONOMIC ZONE (EEZ) OF NEW CALEDONIA. *LE PARC NATUREL DE LA MER DE CORAIL* EXTENDS TO THE BOUNDARIES OF THE EEZ. REGIONS SURVEYED ON THE GLOBAL REEF EXPEDITION ARE LABELED WITHIN THE MAP.



2.0 METHODS

2.1 SITE DESCRIPTIONS

The Global Reef Expedition mapped and surveyed coral reefs in New Caledonia. A total of 74 dive sites were surveyed, among which 554 benthic habitat transects and 504 fish surveys were completed. The dive sites were selected based on accessibility by boat and with the goal of including all coral reef habitat types (Figure 3a).

The extensive surveys, described herein, were selected to include remote, uninhabited locations that, at the time of sampling, had not previously been studied to this extent. The *M/Y Golden Shadow* and its support vessels were graciously donated for use on this expedition to allow KSLOF and New Caledonian researchers to easily gather data in some of the most remote locations of New Caledonia. Table 1 shows the total number of surveys conducted at each atoll.

The Entrecasteaux Atolls are located approximately 40 km north of the barrier reef surrounding Grande Terre and the Belep Islands[1]. The atolls that make up the Entrecasteaux group include: Pelotas, Portail, Surprise, Huon, Petit Guilbert, Gros Guilbert, and Merite. These atolls are uninhabited, and have been no-take areas since 2011, as part of a 2008-listed UNESCO World Heritage Area "Lagoons of New Caledonia." Since 2018, a new management plan also prohibits any visits in several sectors, including Pelotas and Guilbert atolls. The Entrecasteaux Atolls each have an extensive fore reef around their perimeters that drop abruptly into deep ocean water. The lagoons have well-developed patch reefs. The rim has both intertidal and subtidal sections, which are bisected by large passes. These characteristics allow for unique reef and fish communities to flourish. The atolls have little emergent land, apart from Huon, which has an approximately 3 km strip of exposed sand and is the home to a large population of birds and one of the largest sea turtle nesting sites in the West Pacific. Surprise has two islets, which also harbor important bird colonies and sea turtle nesting sites[8].

Cook Reef is the most northern portion of the barrier reef surrounding Grande Terre and the Belep Islands. The barrier reef surrounding Grande Terre is one of the longest barrier reefs in the world[9,10], measuring approximately 1,500 km in length, encompassing a massive (40,000 km^2) shallow lagoon[1]. This section of the barrier reef is also a UNESCO World Heritage Area.

Table 1 TOTAL NUMBER OF DIVE SITES AND TRANSECTS COMPLETED AT EACH ISLAND IN 2013.

LOCATION	NUMBER OF DIVE SITES	NUMBER OF BENTHIC TRANSECTS	NUMBER OF FISH TRANSECTS
COOK REEF	12	79	77
PRONY BAY	3	20	26
ILE DES PINS	20	119	150
PETIT GUILBERT	2	15	14
GROS GUILBERT	2	18	12
HUON	14	124	96
MERITE	2	16	14
PELOTAS	4	39	19
PORTAIL	5	42	36
SURPRISE	10	82	60

Figure 2 AERIAL PHOTOGRAPH OF PRONY BAY, NEW CALEDONIA, SHOWING THE SILT RUNOFF FROM NICKEL MINING (SEE ARROWS).

At the opposite end of the main island in New Caledonia, at the southern end of Grande Terre, Prony Bay is bordered with red clay rich in metal, and runoff from natural erosion and nickel mines on the mainland can impact the bay. These mines have been utilized for well over a century (Figure 2)[9]. There are also natural hydrothermal vents in Prony Bay with chimneys extending over 30 meters high, some reaching to within a few meters of the surface[11]. This environment has allowed for unique coral reef communities to adapt to unusual conditions and host dominant coral genera not found in other areas of New Caledonia[11].

Ile des Pins is an uplifted carbonate island surrounded by an extensive reef system, located south of the barrier reef surrounding the Grande Terre lagoon. The island has a population of approximately 2,000 people and is frequently visited by tourists[5]. It is also a UNESCO World Heritage Area since 2008 and has been subjected to periodic monitoring every four years since then.

2.2 HABITAT MAPPING

High-resolution habitat and bathymetric maps were created for shallow-water marine environments found within the lagoon and for reefs using multispectral WorldView-2 satellite imagery obtained from DigitalGlobe Inc., in combination with data obtained from aerial surveys and ground-truthing (see examples of map outputs in Figures 3a-c). These maps and the related data will be useful not only for marine spatial planning, but also as a reference for future research on New Caledonia's coral reefs. The maps extend from the shoreline to approximately 25 m water depth. Prior to the field surveys, an aerial survey of each island's coastline and adjacent shallow marine habitat was undertaken. Ground-truthing, which was used to define habitat classes, and guide interpretation of the remote sensing data, 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 3a THESE THREE EXAMPLE MAP OUTPUTS ARE OF ILE DES PINS, NEW CALEDONIA. 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 3b

HABITAT MAP WITH CLASSIFICATIONS

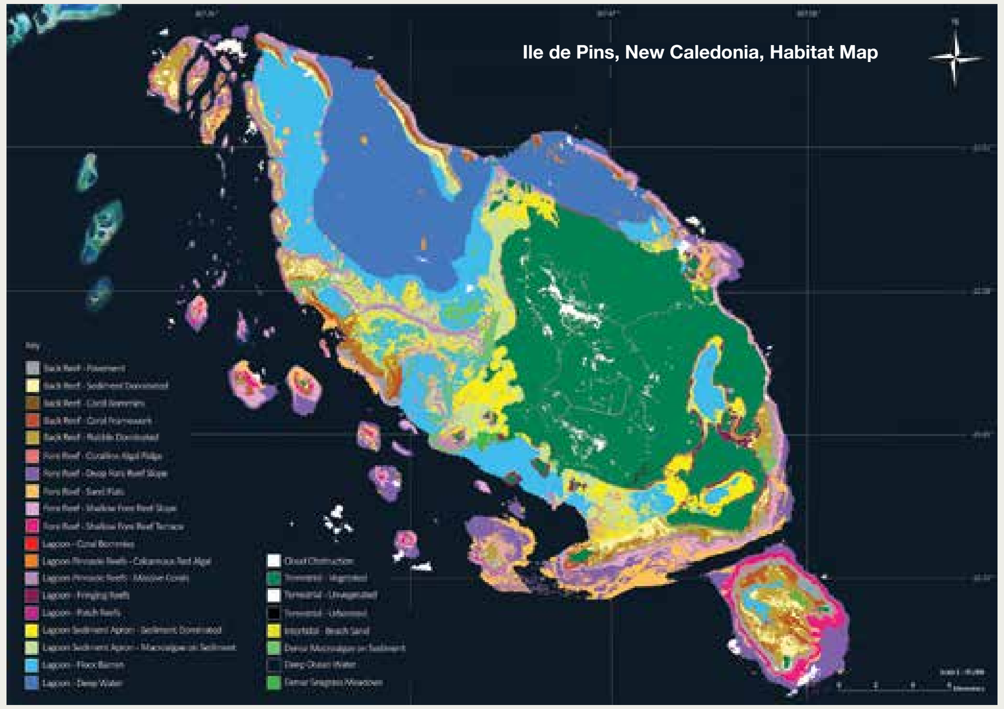
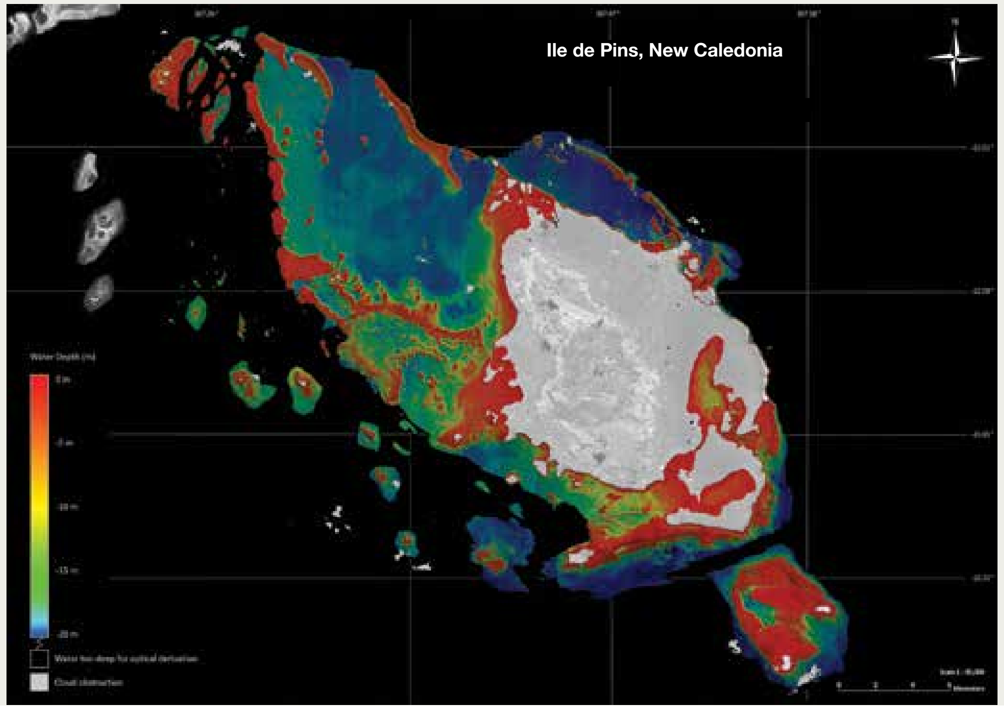


Figure 3c

BATHYMETRY MAP WITH DEPTHS



2.2 a SATELLITE IMAGERY

A total of 2,662 km^2 of DigitalGlobe Inc. WorldView-2 (8-band) satellite imagery was purchased by KSLOF for the regions mapped in New Caledonia. The satellite images had a spatial resolution of 2×2 m (each pixel covers a 4 m^2 area), enabling scientists in the field to locate features of interest. KSLOF fellows from Nova Southeastern University 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.

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 4) by the KSLOF fellows. At each point, 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, the laptop operator watched the video in real time and guided the drop-cam operator to raise or lower the camera to avoid hitting anything on the seafloor. In this manner, any damage to marine life was prevented. The video was recorded on a ruggedized laptop with 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 length of the tether cable (50 m).

Figure 4

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, ground-truthing, and benthic video surveys. The combination of all data collected was used for development of a habitat classification scheme and training of *eCognition* software to develop object-based classification models. 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. 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 5). 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. 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 5 ACOUSTIC SONARS USED IN THE SURVEYS. SUB-SEABED PROFILER (LEFT) AND SINGLE-BEAM SONAR (RIGHT).

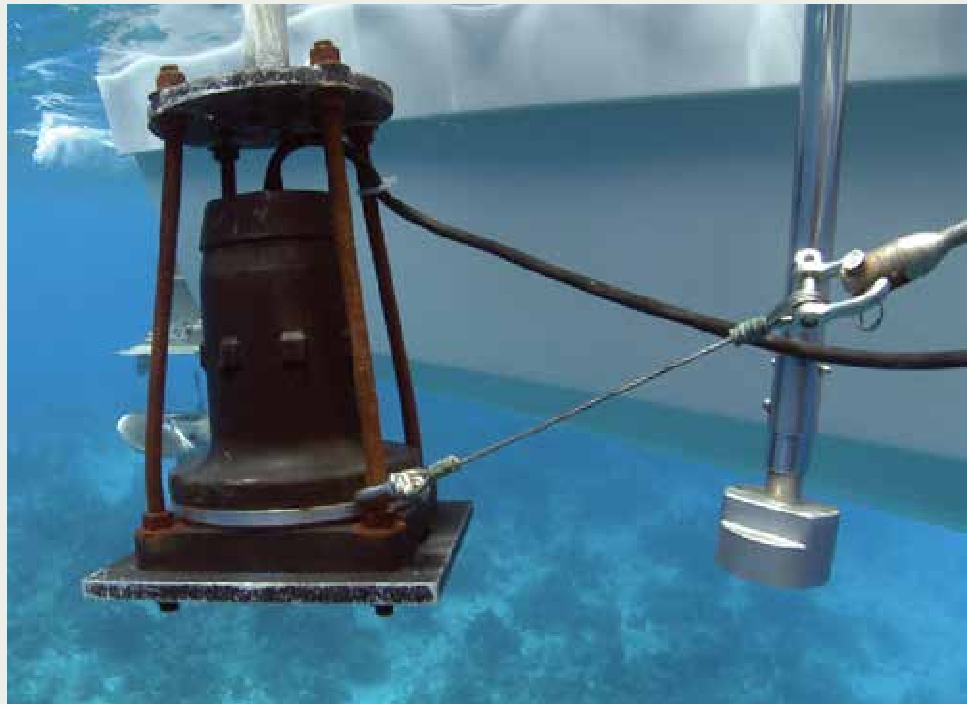


Table 2 CLASSES OF BENTHIC HABITAT USED FOR MAPPING AND AREA CALCULATIONS. THE MEASUREMENT OF EACH AREA IS PRESENTED IN TABLE 3 FOR EACH OF THE LOCATIONS SURVEYED. KSLOF COMBINED SOME HABITATS (RIGHT COLUMN) UNDER A BROADER CLASSIFICATION (LEFT COLUMN) FOR THE PURPOSES OF THIS REPORT.

HABITAT CLASSIFICATIONS	
Back reef coral	Back reef coral bommies
	Back reef coral framework
Deep fore reef 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 fore reef community	Shallow fore reef slope
	Shallow fore reef terrace
Fore reef sand flats	
Dense seagrass meadows	
Mud flats	
Reef top algal mats	
Terrestrial	Beach sand
	Terrestrial vegetation
	Unvegetated terrestrial
Wetlands	
Urban	

2.3 CORAL REEF COMMUNITY SURVEYS

The 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 New Caledonia. 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

Benthic cover (Box 1) was assessed along 10 m transects using recorded observations and/or photographic assessments making note of the substrate type and the amount of seafloor covered by major functional groups. The major functional groups included: corals (identified to genus), other sessile invertebrates (identified to phylum or class), and six functional groups of algae. At least two KSLOF surveyors using SCUBA recorded observations 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 6). 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 point-intercept surveys at every depth, 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 7) at each depth. As before, where possible, the diver completed at least one survey at 20, 15, 10, and 5 m depth at each site. In order to determine benthic community composition, coral, and algae cover, 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)[12]. 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 8). These data were then exported into a Microsoft Excel spreadsheet and added to the benthic survey database for further analysis.

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 the island is presented as the measure of each substrate type. To further analyze the coral and algal cover, the sum of the specific algae types or coral

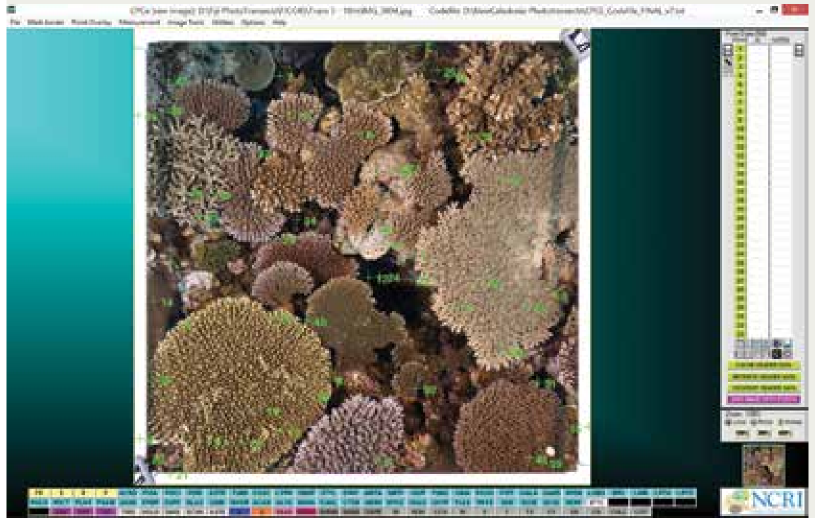
Figure 6 A DIVER CONDUCTING A BENTHIC SURVEY. DIVER USES A 10 M TRANSECT LINE AND RECORDS BENTHIC SUBSTRATE TYPE AND COVER EVERY 10 CM. PHOTO BY KEN MARKS.

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 7 A DIVER TAKES A PHOTO OF A 1 M × 1 M SQUARE QUADRAT. TEN PHOTOS FOR EACH TRANSECT ARE COMPLETED AT DIFFERENT DEPTHS AND SUPPLEMENTAL DATA IS COLLECTED USING TRANSECT LINES AS SHOWN IN FIGURE 6. PHOTO BY PHILIP RENAUD.

Figure 8 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.



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 12.

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[13]. 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 at each of the sites. The survey transects covered depths between 1 and 22 m, but most of the surveys were between 5 and 20 m depth (Figure 9). Transects were deployed at deep (>12 m) and shallow (<10 m) 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 at each site. The fish assemblages at each dive site were surveyed using a fish visual census technique modified from the survey principles described by English et al. (1994)[14]. 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[15–18] and their lengths were 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[19–23]. Abundance and biomass data were then converted and represented as density by individuals/100 m^2 and biomass by kg/100 m^2.

The counted fish were also attributed to trophic-level categories based on diet by species[22]. 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[24]. 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)[25]. 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 2.6-3.0 are typically small in size and are not considered important to local fisheries[26].

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 that otherwise would impede the settlement of juvenile corals[27,28]. These fish include damselfish, tangs, surgeonfish, butterflyfish, and a few small-bodied parrotfish. Fish in trophic levels 3.1-4.0 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 levels 4.1-4.5 are typically considered top predators and prey on finfish of the lower trophic levels. These predatory fish include large wrasse, grouper, hawksfish, snapper, goatfish, and sharks. The majority of the fish important to local fisheries are found in trophic levels 3.6-4.0 and 4.1-4.5[26].

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 9 SCIENTIST RECORDS FISH OBSERVED ALONG A 30 M × 4 M TRANSECT OVER A 10- TO 15-MINUTE PERIOD. PHOTO BY KEN MARKS.

3.0 RESULTS

3.1 HABITAT MAPPING

A total of 2,662 km² of satellite imagery, 593 drop-cam videos, and nearly 3 million depth soundings were used to map the Entrecasteaux Atolls, Cook Reef, Prony Bay, and Ile des Pins, New Caledonia. Overall, the total reef habitat types (i.e., substrate with meaningful coverage of live coral colonies) including back reef coral, lagoonal coral, lagoonal pinnacle reefs, lagoonal patch reefs, and fore reef communities covered about 330 km². The fore reef communities, which include deep and shallow fore reef slopes and terrace, measured 214 km², which is where the majority of the reef habitat was observed for New Caledonia (Table 3). The lagoonal and back reef communities totaled 119 km².

Most of the mapped fore reefs habitats were found surrounding Ile des Pins and Cook Reef, measuring 65 km² and 58 km², respectively. The fore reef habitats of the Entrecasteaux Atolls ranged from 4.2 to 38 km², with Surprise having the largest fore reef area. The back reef coral habitats were most dominant around the Entrecasteaux Atolls and Ile des Pins. Of the lagoonal coral dominated habitats, lagoonal coral with massive coral dominated habitat were the most abundant, particularly at Surprise, Huon, Ile des Pins, Prony Bay, and Cook Reef. Prony Bay was the only area with lagoonal pinnacle reefs dominated by branching coral, measuring 16 km², which was unique among all other areas mapped in New Caledonia.

Table 3 TOTAL AREA (KM²) OF HABITAT TYPE, BY ISLAND, CALCULATED FROM HABITAT MAPS. DASHES INDICATE NO HABITAT TYPE FOUND AT THAT LOCATION.

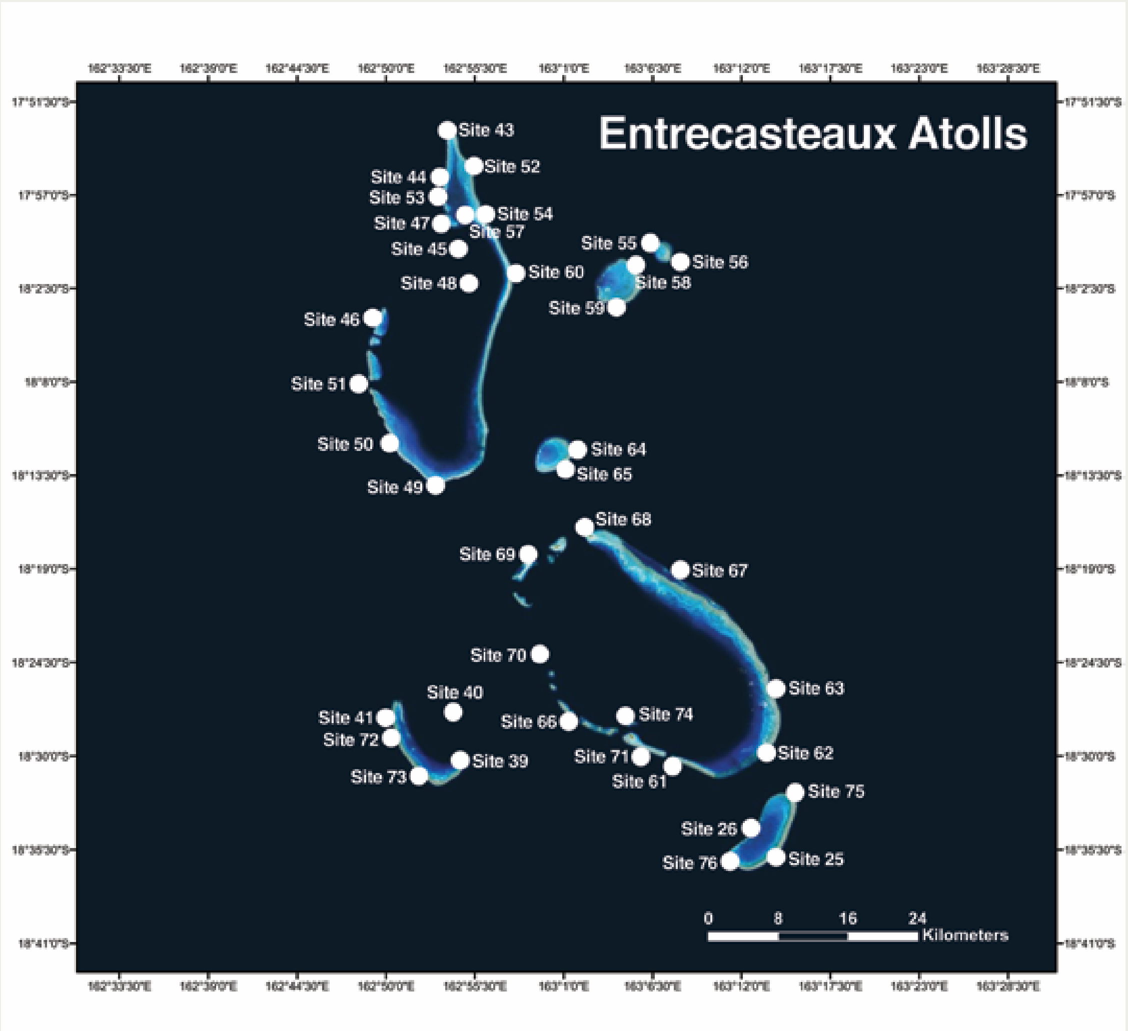
	TOTAL AREA (SQUARE KM)									
HABITAT CLASSIFICATIONS	Cook Reef	Prony Bay	Ile des Pins	Petit Guilbert	Gros Guilbert	Huon	Merite	Pelotas	Portail	Sur-prise
Back reef coral	6.78	--	12.01	0.53	2.17	3.19	0.60	2.90	3.42	9.97
Deep fore reef slope	29.96	--	35.32	2.50	5.50	10.31	1.56	1.75	4.17	17.52
Deep lagoonal water	270.23	154.58	89.04	--	--	189.59	--	--	--	350.46
Lagoonal coral	10.14	30.89	20.82	--	0.06	6.35	0.20	0.36	0.92	7.95
Lagoonal substrate	37.43	44.38	162.70	1.37	9.77	87.11	7.20	16.92	9.29	57.87
Lagoonal macroalgae-dominated substrate	2.53	2.29	25.76	--	--	16.41	--	4.29	2.48	14.85
Nearshore algal communities	0.53	--	2.32	--	0.56	2.29	0.13	0.26	0.61	1.40
Dense macroalgae on sediment	2.66	--	8.81	0.13	3.68	5.26	1.82	--	--	--
Shallow fore reef community	27.75	--	29.65	2.54	2.85	9.21	3.16	2.45	8.28	19.20
Fore reef sand flats	7.13	--	20.67	0.57	0.19	1.74	0.59	0.21	0.14	6.26
Dense seagrass meadows	1.76	--	1.59	--	--	--	--	--	--	--
Mud flats	--	1.29	--	--	--	--	--	--	--	--
Reef top algal mats	--	2.58	--	--	--	--	--	--	--	--
Terrestrial	--	108.35	158.17	--	--	--	--	--	--	0.60
Wetlands	--	--	--	--	--	--	--	--	--	--
Urban	--	--	0.34	--	--	--	--	--	--	--

3.2 a BENTHIC COVER ASSESSMENT ENTRECASTEAUX ATOLLS

The Entrecasteaux Atolls were the northernmost group of atolls surveyed in New Caledonia (Figure 10). The dominant substrate of the atolls is hard bottom or pavement with coral and algal cover varying by location, shown in Figure 11.

Pelotas has the highest live coral cover recorded in the Entrecasteaux group, accounting for 47% of the substrate (±4% S.D.; 4 sites; 39 transects; Figure 11). There was an even distribution of live coral throughout all depths surveyed around the atoll. In other instances, such as sites in Portail, higher than average coral cover was observed at specific depth gradients. Pelotas was dominated by *Acropora,* which accounted for 50% (±23% S.D.; 4 sites; 39 transects) of the live coral recorded. At Pelotas, Site 26 had notably higher

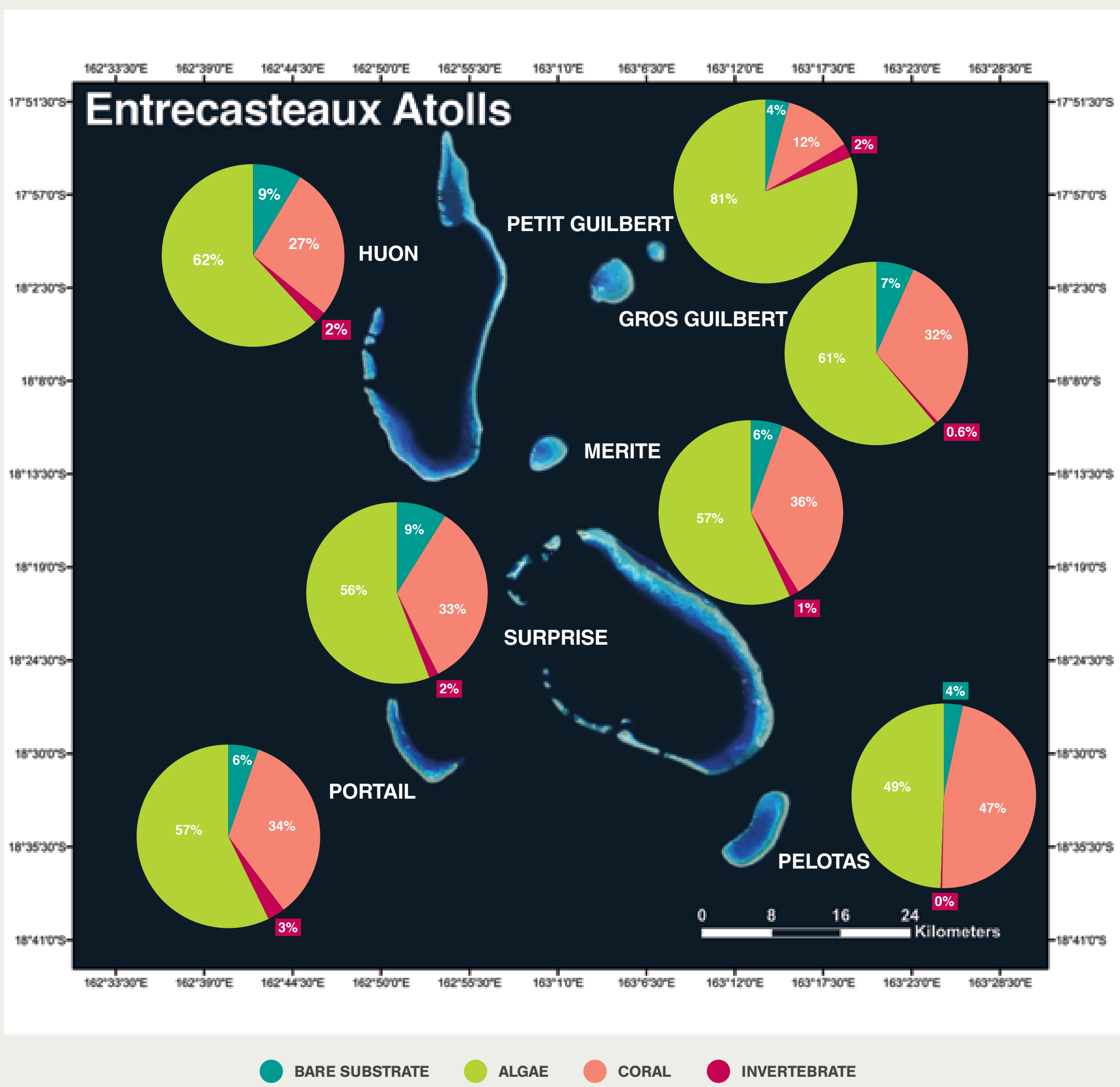
Figure 10 BENTHIC AND FISH SURVEY LOCATIONS OF THE ENTRECASTEAUX ATOLLS, NEW CALEDONIA.



than average *Millepora* cover, accounting for 26% (±14% S.D.; 8 transects) of the live coral recorded. The coral diversity of the atoll was relatively low at 0.68 on the Simpson Index, likely due to the strong dominance of *Acropora* observed.

Algae covered 47% (±4% S.D.; 4 sites; 39 transects) of the substrate at Pelotas, with the dominant alga being crustose coralline algae (CCA) and turf **(Figure 12)**. CCA accounted for 45% (±15% S.D.; 4 sites; 39 transects) of the total algae recorded, and turf accounted for 39% (±8% S.D.; 4 sites; 39 transects). Site 26 had higher than average macroalgae recorded, which, combined with the higher *Millepora* presence, could indicate nutrient input to the area[29]. Pelotas is the southernmost atoll, located at the edge of the deep channel separating the Entrecasteaux Atolls and Cook Reef. This channel may be bringing in nutrient pulses or create upwelling events around Pelotas; however, this has not been measured directly and should be explored further. Previous studies of the southern reefs of New Caledonia show eddies and upwelling events are common, and similar upwelling events may be occurring in the northern atolls as well[2,30].

Figure 11 AVERAGE BENTHIC COVER (%) OF EACH ISLAND SURVEYED IN THE ENTRECASTEAUX ATOLLS, NEW CALEDONIA. THE SUBSTRATE TYPES ARE BARE SUBSTRATE, ALGAE, LIVE CORAL, AND INVERTEBRATES. THESE VALUES WERE CALCULATED FROM THE BENTHIC SURVEYS, AVERAGING BY DEPTH, THEN SITE. NUMBER OF TRANSECTS (N) AT EACH ATOLL: PETIT GUILBERT, N=15; GROS GUILBERT, N=18; HUON, N=124; MERITE, N=16; PELOTAS, N=39; PORTAIL, N=42; SURPRISE, N=82.



Merite, Portail, Surprise, and Gros Guilbert atolls all have similar benthic cover. Live coral accounted for 32-36% of the substrate, and algae covered between 56 and 60% of the substrate, although the algal community varied slightly among each atoll. The algal community of Merite was dominated by turf algae, accounting for 43% (±4% S.D.; 2 sites; 16 transects) of the total algae observed **(Figure 12)**. CCA was the second most dominant algae accounting for 31% (±8% S.D.; 2 sites; 16 transects) of the algae recorded for this location **(Figure 12)**. Interestingly, Merite also had the highest percentage of cyanobacteria of all the reefs surveyed on the GRE mission to New Caledonia, accounting for 18% (±4% S.D.; 2 sites; 16 transects) of the algae recorded. Matting cyanobacteria is known to compete with live coral and can take up valuable substrate space for new coral recruits to settle[31]. This is worth noting and, if possible, should be monitored further. Portail, Surprise, and Gros Guilbert algal communities were dominated by CCA, accounting for 42% (±12% S.D.; 5 sites; 42 transects), 46% (±12% S.D.; 10 sites; 82 transects), and 49% (±8% S.D.; 2 sites; 18 transects), respectively. Portail had the highest macroalgal cover recorded in the Entrecasteaux Atolls, accounting for 13% (±3% S.D.; 5 sites; 42 transects) of the algae recorded.

Acropora dominated the live coral cover at Merite, Portail, Surprise, and Gros Guilbert atolls. Although it was the most dominant coral, *Acropora* only accounted for 29% (±10% S.D.; 5 sites; 42 transects) of the coral recorded at Portail. This atoll was the most biodiverse location surveyed in the Entrecasteaux Atolls, with a diversity index of 0.88, calculated using the Simpson Index of Diversity. Merite and Surprise atolls had lower diversity indices. Merite had a strong dominance of *Acropora,* bringing the indices down to 0.63, the lowest diversity of all the sites surveyed in New Caledonia, and Surprise had a diversity index of 0.77. We observed higher than average percentages of live coral at sites located on the southernmost end of Surprise atoll, specifically at sites 61 and 62. The live coral cover at these sites was like that observed at its nearby neighbor, Pelotas.

The atolls with the lowest live coral cover were Petit Guilbert and Huon, the northernmost atolls surveyed in New Caledonia **(Figure 11)**. These atolls had 12% (±7% S.D.; 2 sites; 15 transects) and 27% (±7% S.D.; 14 sites; 124 transects) live coral cover, respectively. The substrate at these atolls were dominated by CCA and turf algae, combined accounting for 65% of the total algae at Petit Guilbert and 81% of the algae of Huon **(Figure 12)**. Petit Guilbert also had a notable presence of cyanobacteria and erect calcareous algae. Cyanobacteria accounted for 18% (±9% S.D.; 2 sites; 15 transects), and erect calcareous algae accounted for 12% (±12% S.D.; 2 sites; 15 transects) of the total algae recorded. The highest percentage of cyanobacteria, 25% (±24% S.D.; 2 sites; 15 transects) was observed at Site 55 at Petit Guilbert, with most being observed at 20-25 m depth.

The coral communities at these two atolls differed slightly but were both dominated by *Acropora.* At Petit Guilbert, *Acropora* and *Porites* were the two most dominant coral genera accounting for 13% (±14% S.D.; 2 sites; 15 transects) and 28% (±36% S.D.; 2 sites; 15 transects) of the live coral observed, respectively. Huon, although dominated by *Acropora*, had a more diverse assemblage of coral genera, similar to that observed at Portail with a coral diversity index of 0.85. Site 48, found on the exposed side of Huon, had a much higher percentage of coral observed at 25 m depth, which was not observed at other locations in the Entrecasteaux Atolls.

3.2 b COOK REEF

Cook Reef is a finger-like extension found at the northernmost end of the barrier reef forming the lagoon around Grande Terre. This reef is located approximately 40 km south of the Entrecasteaux Atolls and has a spur and groove reef topography. Surveys around Cook Reef included exposed and protected portions of the fore reef habitat (Figure 13). Live coral accounted for 22% (±8% S.D.; 12 sites; 79 transects) of the substrate (Figure 14). The dominant genera were *Acropora* and *Porites*, making up 28% (±10% S.D.; 12 sites; 79 transects) and 12% (±12% S.D.; 12 sites; 79 transects) of the live coral cover, respectively. The coral diversity of Cook Reef was slightly higher than that observed at Portail in the Entrecasteaux Atolls in the north, with an index of 0.89.

Algae covered 68% (±8% S.D.; 12 sites; 79 transects) of the benthos around Cook Reef and was dominated by CCA, accounting for 50% (±12% S.D.; 12 sites; 79 transects) of the algae recorded (Figure 12). Turf algae was the second most dominant alga, accounting for 29% (±13% S.D.; 12 sites; 79 transects) of the growth forms observed. The cyanobacteria found at Cook Reef was the second highest percentage of algae recorded in New Caledonia during the GRE, measuring only 4% less than what was observed at Merite. There was no consistency by depth or site to the frequency of cyanobacteria recorded, making it hard to determine whether the high concentrations were an isolated event.

Figure 12 RELATIVE COMPOSITION OF ALGAE (%) AT EACH SITE SURVEYED AT NEW CALEDONIA. 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 IS LISTED WITHIN THE GRAPH FOR EACH SITE. COOK REEF, N=79; PETIT GUILBERT, N=15; GROS GUILBERT, N=18; HUON, N=124; MERITE, N=16; PELOTAS, N=39; ILE DES PINS, N=119; PORTAIL, N=42; PRONY BAY, N=20; SURPRISE, N=82.

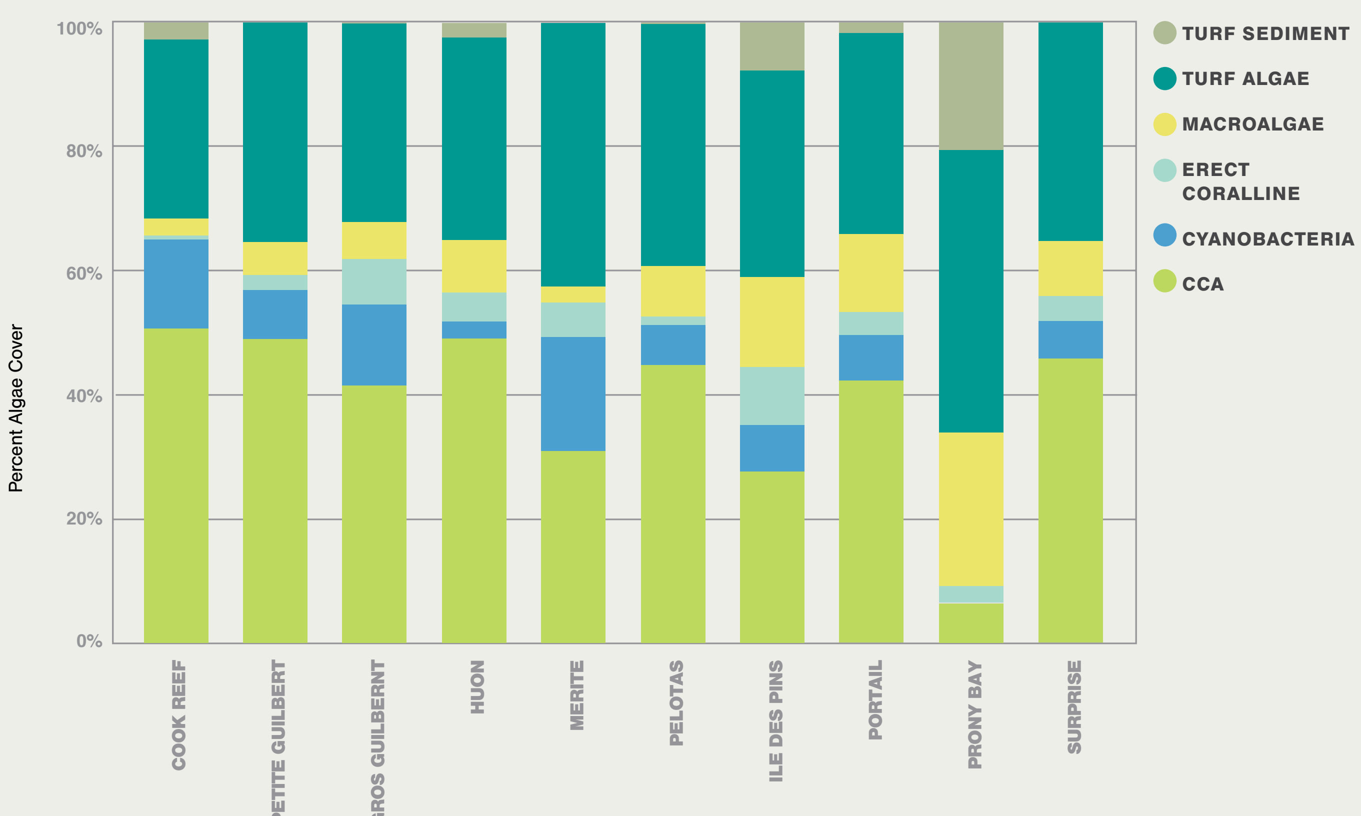


Figure 13 BENTHIC AND FISH SURVEY LOCATIONS OF THE COOK REEF, NEW CALEDONIA.

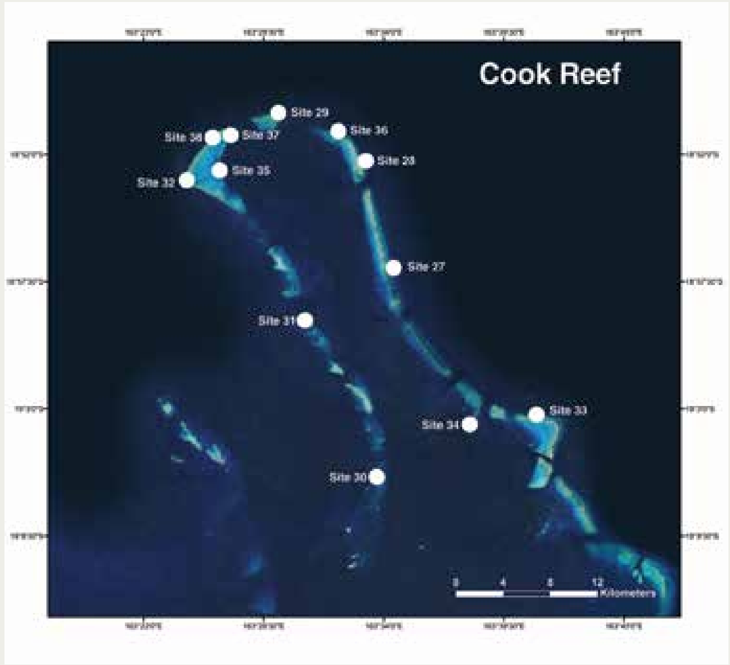
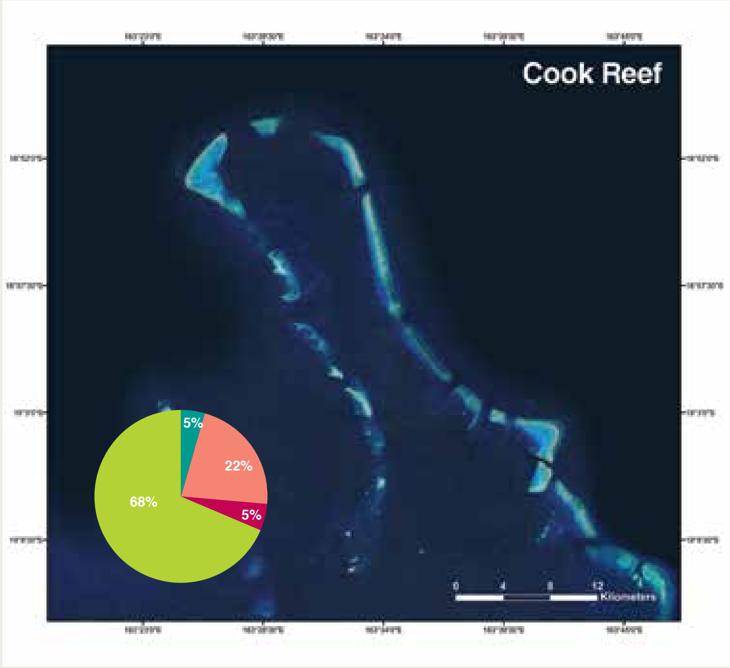


Figure 14 AVERAGE BENTHIC COVER (%) IN COOK REEF, NEW CALEDONIA. THE SUBSTRATE TYPES ARE BARE SUBSTRATE, ALGAE, LIVE CORAL, AND INVERTEBRATES. THESE VALUES WERE CALCULATED FROM THE BENTHIC SURVEYS, AVERAGING BY DEPTH, THEN SITE. NUMBER OF TRANSECTS (N) AT EACH LOCATION: N=79.



3.2 c PRONY BAY

Prony Bay was the most peculiar location surveyed in New Caledonia. Being located so close to Grande Terre (Figure 15) and known to have high sedimentation, low live coral cover would normally be expected. Surprisingly, the exact opposite was found. Prony Bay had the highest percentage of live coral cover observed when compared with all other locations surveyed in New Caledonia. Live coral cover accounted for 53% (±17% S.D.; 3 sites; 20 transects) of the substrate (Figure 16). This is 7% higher than what was observed at Pelotas, the highest of the Entrecasteaux Atolls, and 32% higher than that found around Ile des Pins, located directly to the south of Prony Bay. The coral community at Prony Bay, similar to the other sites of New Caledonia, was dominated by *Acropora*, which accounted for 39% (±17% S.D.; 3 sites; 20 transects) of the coral recorded. Interestingly, the bay had a much higher percentages of *Turbinaria, Leptoseris,* and *Pachyseris* than what was observed at all other sites. This indicates these coral genera may have been able to adapt to this unlikely habitat, creating a unique coral community; however, this should be explored further. Even with the unique coral community, the diversity was lower than that observed at nearby Ile des Pins, with a diversity index of 0.78. This lower diversity could be due to "super corals" being better adapted to the turbid conditions[32–34].

Contrary to what was observed in the Entrecasteaux Atolls and Cook Reef, CCA was not the dominant algae found in Prony Bay. Turf algae, turf algae with sediment, and macroalgae were the most dominant algae observed (Figure 12). This is not unexpected given the high runoff from the nickel mining occurring on the hills surrounding Prony Bay. The runoff is likely introducing new nutrients into the water, allowing for fleshy algae to flourish. However, we did not take nutrient samples, so this should be studied further.

Figure 15 BENTHIC AND FISH SURVEY LOCATIONS OF PRONY BAY, NEW CALEDONIA.

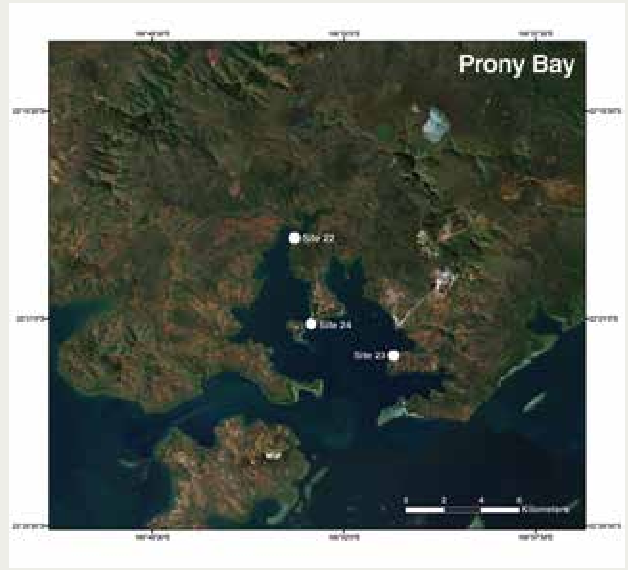
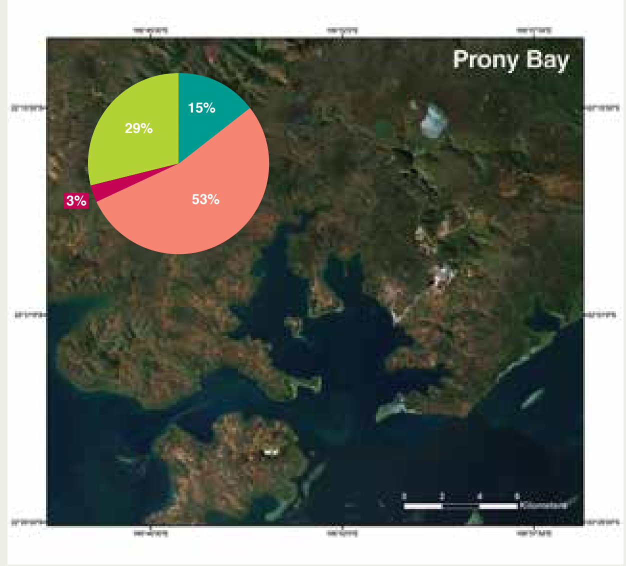


Figure 16 AVERAGE BENTHIC COVER (%) IN PRONY BAY, NEW CALEDONIA. THE SUBSTRATE TYPES ARE BARE SUBSTRATE, ALGAE, LIVE CORAL, AND INVERTEBRATES. THESE VALUES WERE CALCULATED FROM THE BENTHIC SURVEYS, AVERAGING BY DEPTH, THEN SITE. NUMBER OF TRANSECTS (N) AT EACH LOCATION: N=20.



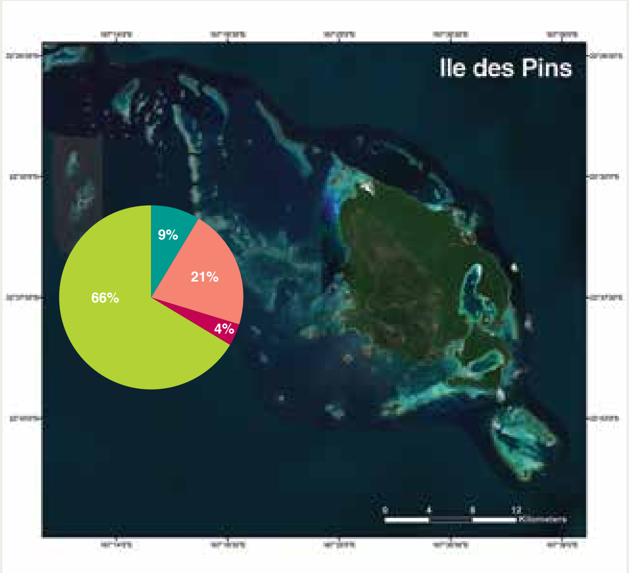
3.2 d ILE DES PINS

Ile des Pins is an island located adjacent to the southernmost portion of the barrier reef surrounding Grande Terre. This island is commonly visited by tourists and has a permanent population of 2,000[5]. The reefs surrounding Ile des Pins had the lowest live coral cover observed in New Caledonia (Figure 17). Live coral only accounted for 21% (±9% S.D.; 20 sites; 119 transects) of the substrate (Figure 18). Of the coral measured, the dominant genus was *Acropora*, accounting for 25% (±12% S.D.; 20 sites; 119 transects) of the total coral recorded, followed by *Porites* and *Montipora*, accounting for 11% (±8% S.D.; 20 sites; 119 transects) and 11% (±6% S.D.; 20 sites; 119 transects), respectively. However, the diversity of coral genera was some of the highest observed in New Caledonia, 0.88, only slightly lower than Cook Reef and the same as Portail in the north.

Algae accounted for 66% (±9% S.D.; 20 sites; 119 transects) of the substrate around Ile des Pins, with the dominant algae being turf (Figure 12). CCA was the second most dominant algae observed, accounting for 28% (±12% S.D.; 20 sites; 119 transects) of the algae recorded. The algal community of Ile des Pins had the highest percentage of erect calcareous algae observed in New Caledonia. The erect calcareous algae group is described as made up of calcifying macroalgae, such as *Halimeda*. Erect calcareous algae accounted for 9% (±8% S.D.; 20 sites; 119 transects) of the algae observed at Ile des Pins. Guilbert of the Entrecasteaux Atolls was the only other location with a notable erect calcareous algae presence, where it accounted for 7% (±9% S.D.; 4 sites; 33 transects) of the total algae observed.

Figure 17 BENTHIC AND FISH SURVEY LOCATIONS AT ILE DES PINS, NEW CALEDONIA.

Figure 18 AVERAGE BENTHIC COVER (%) IN ILE DES PINS, NEW CALEDONIA. THE SUBSTRATE TYPES ARE BARE SUBSTRATE, ALGAE, LIVE CORAL, AND INVERTEBRATES. THESE VALUES WERE CALCULATED FROM THE BENTHIC SURVEYS, AVERAGING BY DEPTH, THEN SITE. NUMBER OF TRANSECTS (N) AT ILE DES PINS IS N=119.



3.3 FISH COMMUNITY ASSESSMENT

In 2013, the fish population in New Caledonia showed a strong distinction between offshore (Entrecasteaux Atolls and Cook Reef) and nearshore (Prony Bay and Ile des Pins) sites. Prony Bay, on the main island, had the lowest mean species richness and biomass of all the locations, and Ile des Pins had the lowest mean fish density (Table 4). These two sites consistently had lower values for all metrics than any of the offshore sites, despite the fact that over a third of the sampling effort was focused between these sites. Pelotas of the Entrecasteaux group had the healthiest fish community with the highest mean biomass, species richness, and fish density of all sites surveyed in New Caledonia.

> Pelotas had the **healthiest fish community with the highest mean biomass, species richness, and fish density** of all sites surveyed in New Caledonia.

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 10 SITES IN NEW CALEDONIA.

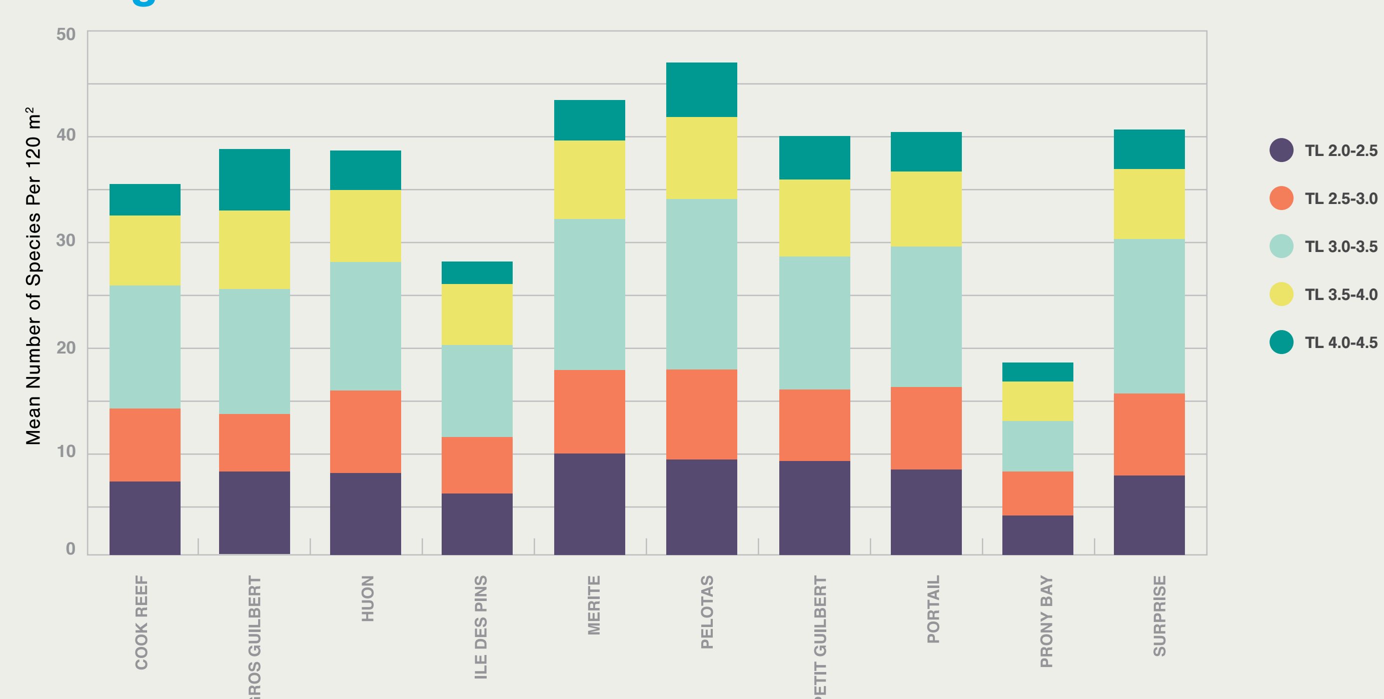
LOCATION/ ISLAND	NUMBER OF SURVEY STATIONS	NUMBER OF REPLICATE TRANSECTS	TOTAL FAMILIES	TOTAL SPECIES	MEAN SPECIES RICHNESS	MEAN DENSITY	MEAN BIOMASS
Ile des Pins	20.0	150.0	40.0	366.0	28.0	119.5	5.5
Prony Bay	3.0	26.0	27.0	153.0	18.3	138.3	2.7
Cook Reef	12.0	77.0	37.0	331.0	35.4	151.5	12.5
Portail	5.0	36.0	35.0	255.0	40.4	177.3	16.2
Huon	14.0	96.0	41.0	323.0	38.6	159.2	13.3
Petit Guilbert	2.0	14.0	28.0	193.0	40.0	162.3	13.1
Gros Guilbert	2.0	12.0	31.0	198.0	38.7	204.0	23.1
Surprise	10.0	60.0	36.0	276.0	40.6	172.9	18.4
Merite	2.0	14.0	29.0	185.0	43.4	180.6	16.1
Pelotas	4.0	19.0	28.0	230.0	47.0	207.9	24.1
TOTAL	**75.0**	**504.0**	**47.0**	**545.0**			
MEAN	**6.8**	**45.8**	**33.1**	**247.0**	**37**	**167.3**	**14.5**

3.3 a SPECIES RICHNESS OF THE FISH ASSEMBLAGE

In total, 545 species from 47 different families were surveyed in New Caledonia during the research period (Table 4). The total number of species surveyed was lowest at Prony Bay (153 species) and highest at Ile des Pins (366 species). However, the high number of species counted at Ile des Pins is likely, in part, a function of increased sampling effort at this site, as approximately 30% of the total transects took place at Ile des Pins. This is evident when calculating the species richness per 30 m × 4 m transect (120 m^2). When calculated by area, Ile des Pins had the second lowest mean species richness, 28.0 species/120 m^2. Prony Bay had the lowest mean species richness at 18.3 species/120 m^2, while Pelotas had the highest, at 47.0 species/120 m^2.

In general, each site had similar proportions of species from each trophic level (Figure 19), indicating that the fish communities at each site share a similar trophic structure. At all sites, trophic levels 3.1-3.5 had the highest species richness of all trophic levels; however, at Prony Bay, this pattern was less pronounced. In all sites except Gros Guilbert, trophic levels 4.1-4.5 had the lowest species richness; at this site, the lowest species richness was found in trophic levels 2.6-3.0. However, the mean number of species in each category varied widely between the offshore and nearshore sites. Prony Bay consistently had the lowest species richness at all trophic levels, while Pelotas had the highest at all trophic levels except 4.1-4.5, which was highest at Gros Guilbert. The largest difference between these two sites was in trophic levels 3.1-3.5 with a mean value of 16.31 species/120 m^2 (+/- 5.83 S.D.) at Pelotas, compared with only 4.85 species/120 m^2 (+/- 3.00 S.D.) at Prony Bay. The smallest difference between the two sites was in the 4.1-4.5 trophic levels, with 5.17 species/120 m^2 (+/- 3.47 S.D.) at Pelotas, and 1.81 species/120 m^2 (+/- 1.17 S.D.) at Prony Bay.

Figure 19 ESTIMATED SPECIES RICHNESS (# OF SPECIES/120 M^2) BROKEN DOWN BY TROPHIC LEVELS AT 10 LOCATIONS IN NEW CALEDONIA.



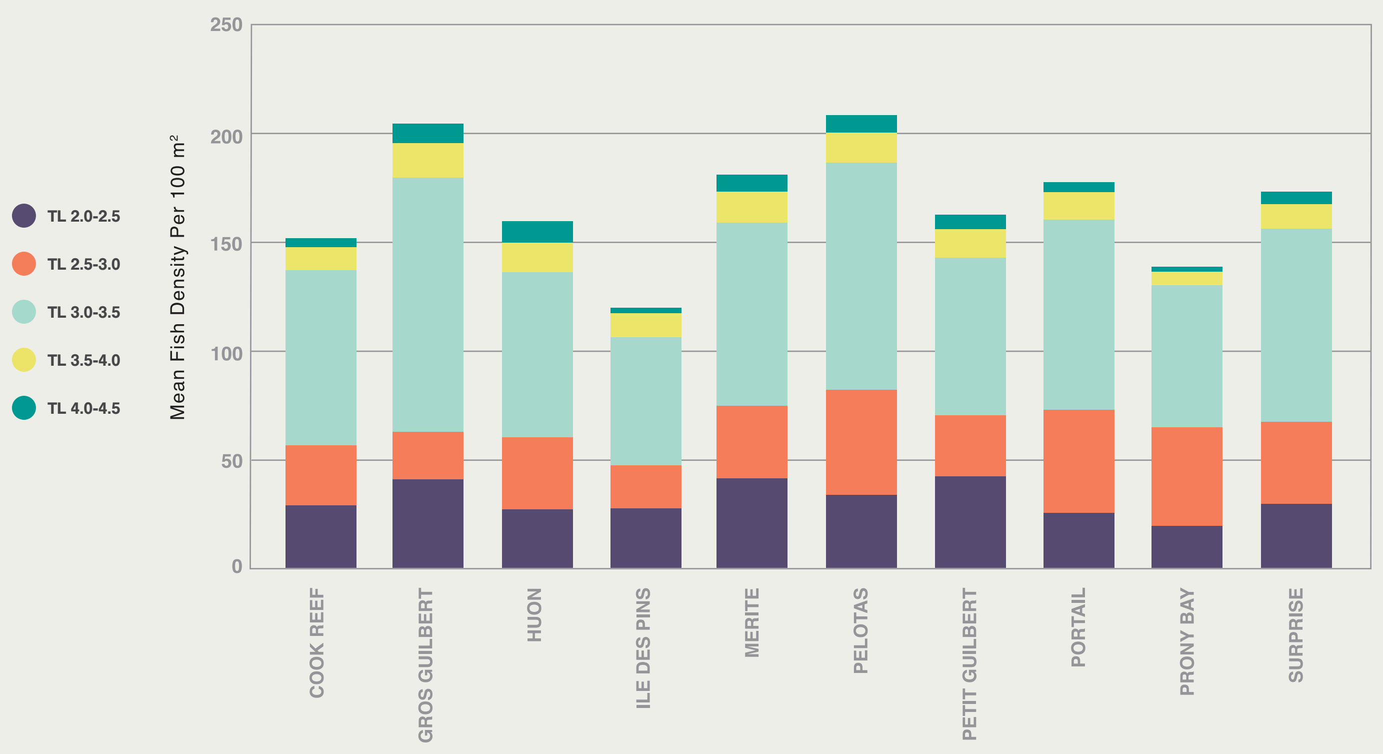
3.3

b FISH DENSITY

The overall mean density of fish in 2013 for all sites surveyed was 165.4 individuals/100 m^2, with the highest mean density found in Pelotas (207.9 individuals/100 m^2) and the lowest in Ile des Pins (119.5 individuals/100 m^2; Table 4, Figure 20).

At all sites, trophic levels 3.1-3.5 had the highest fish density, ranging between 58.71 individuals/100 m^2 (+/- 64.34 S.D.) at Ile des Pins and 116.67 individuals/100 m^2 (+/- 118.55 S.D.) at Gros Guilbert (Figure 20). Across all islands, trophic levels 4.1-4.5 had the lowest fish density, ranging from 2.37 individuals/100 m^2 (+/- 2.13 S.D.) at Ile des Pins to 8.75 individuals/100 m^2 (+/- 12.38 S.D.) at Gros Guilbert. In general, patterns for trophic levels 3.1-3.5, 3.6-4.0, and 4.1-4.5 were consistent; however, patterns between trophic levels 2.0-3.0 differed by site. At Cook Reef, Gros Guilbert, Ile des Pins, Merite, and Petit Guilbert trophic levels 2.0-2.5 had a higher density than trophic levels 2.6-3.0. At all other sites, the pattern was reversed. Interestingly, although Gros Guilbert had the second highest overall mean density (204.0 individuals/100 m^2) and the highest mean density in all trophic categories except 2.6-3.0, the mean density in this category was the second lowest of all of the sites, at 21.94 individuals/100 m^2 (+/- 23.92 S.D.).

Figure 20 ESTIMATED MEAN DENSITY OF FISH (INDIVIDUALS/100 M²) BROKEN DOWN BY TROPHIC LEVEL AT 10 LOCATIONS IN NEW CALEDONIA.



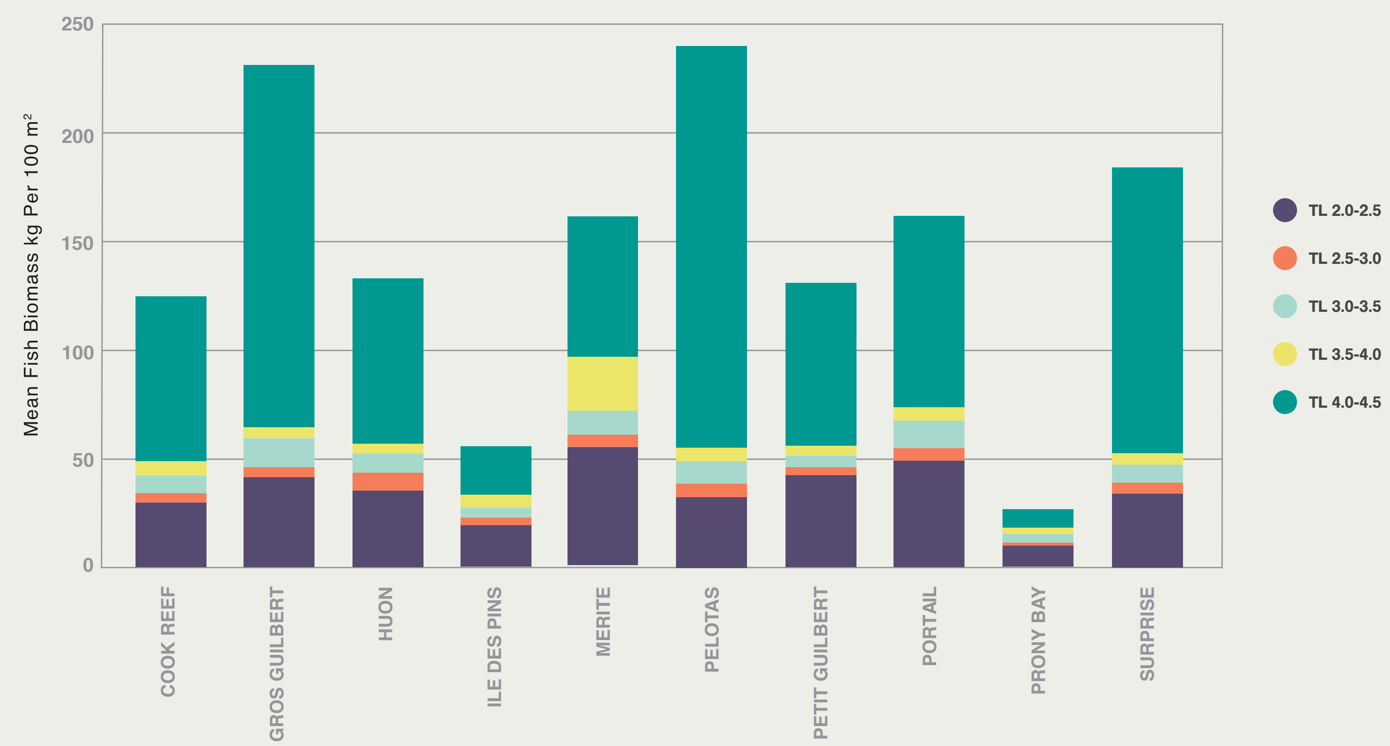
3.3

c FISH BIOMASS

There was a marked difference in fish biomass between nearshore and offshore sites, with Ile des Pins and Prony Bay having much lower mean biomass than the rest of the sites (Figure 21). Prony Bay had the lowest mean biomass (2.7 kg/100 m^2), while the highest mean biomass at Pelotas (24.1 kg/ 100 m^2; Table 4) was almost nine times greater. In fact, the mean biomass at Cook Reef (12.5 kg/ 100 m^2), which was the lowest of the offshore sites, was 2.25 times greater than at Ile des Pins (5.5 kg/ 100 m^2), which had the highest mean biomass of the nearshore sites.

At all sites except Prony Bay, trophic levels 4.1-4.5 made up the largest proportion of the total biomass, indicating the presence of several large apex predators at these sites. At Pelotas and Gros Guilbert, this pattern was particularly dramatic, both with over 70% of the total biomass at that site found in trophic levels 4.1-4.5 (18.52 kg/100 m^2 +/- 24.25 S.D. at Pelotas, 16.70 kg/100 m^2 +/- 31.97 S.D. at Gros Guilbert). At Prony Bay, trophic levels 2.0-2.5 made up the largest proportion of the biomass (0.99 kg/ 100 m^2 +/- 1.30 S.D.). In general, trophic levels 2.6-3.0 had the lowest biomass, except at Huon and Pelotas, where the biomass was lowest in trophic levels 3.6-4.0. Interestingly, Merite had far more biomass in the 3.6-4.0 trophic levels (2.49 kg/100 m^2 +/- 7.39 S.D.) than any of the other sites. For reference, Cook Reef had the second highest biomass in these trophic levels at 0.66 kg/100 m^2 (+/- 1.14 S.D.), approximately a quarter of that at Merite.

Figure 21 ESTIMATED MEAN BIOMASS OF FISH (KG/100 M²) BROKEN DOWN BY TROPHIC LEVEL AT 10 LOCATIONS IN NEW CALEDONIA.

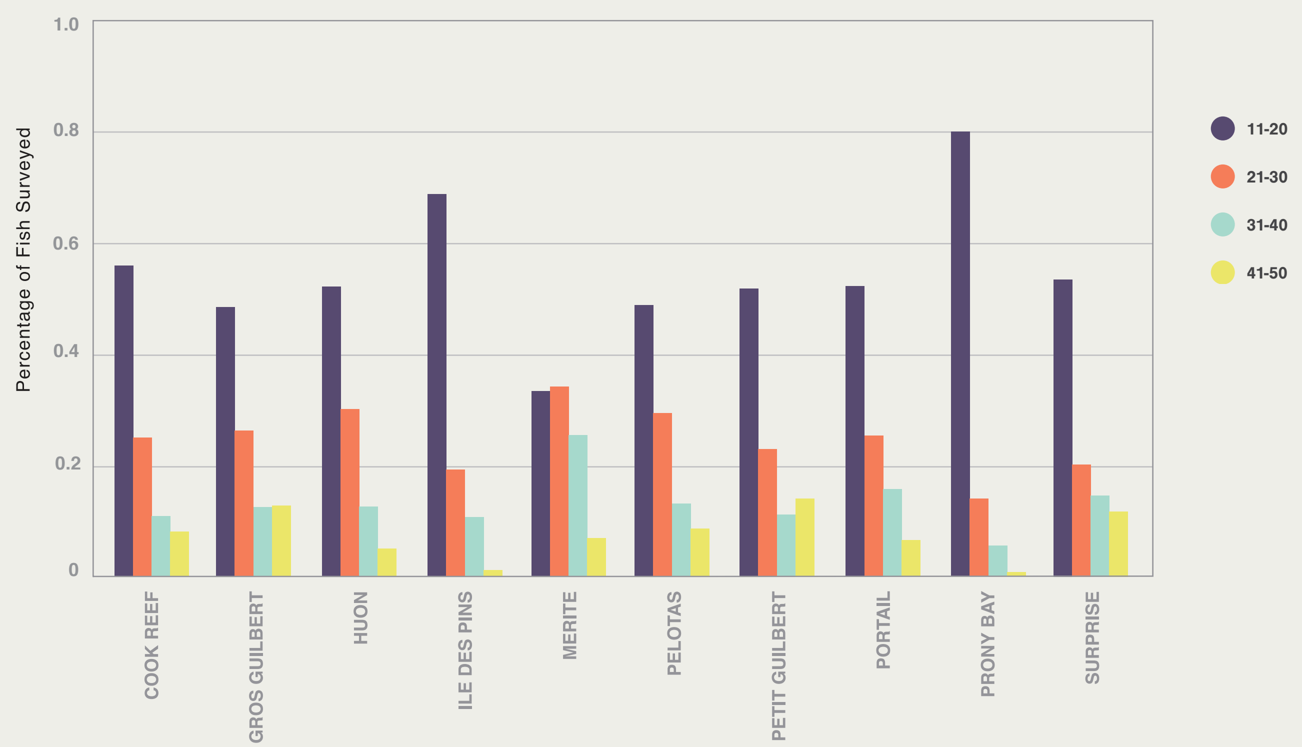


3.3 d SIZE DISTRIBUTION OF FISH

Small fish (11-20 cm) made up the largest proportion of fish surveyed at all sites except Merite, where the highest proportion of fish were 21-30 cm (Figure 22). The fish communities at nearshore sites were characterized by smaller fish than the offshore sites. Prony Bay had the highest proportion of small fish, with 80.0% of fish in the 11-20 cm size category. Prony Bay also had the lowest proportion of large fish, with only 0.7% of the fish surveyed in the 41-50 cm category. Ile des Pins followed a similar pattern, although the fish were slightly bigger at this site. In contrast, the offshore sites had lower proportions of fish in the 11-20 cm category, ranging from 33.4% at Merite to 56.0% at Cook Reef. Larger fish were more common at these sites as well, with fish in the 41-50 cm category making up between 5.1% (Huon) and 14.1% (Petit Guilbert) of the fish surveyed.

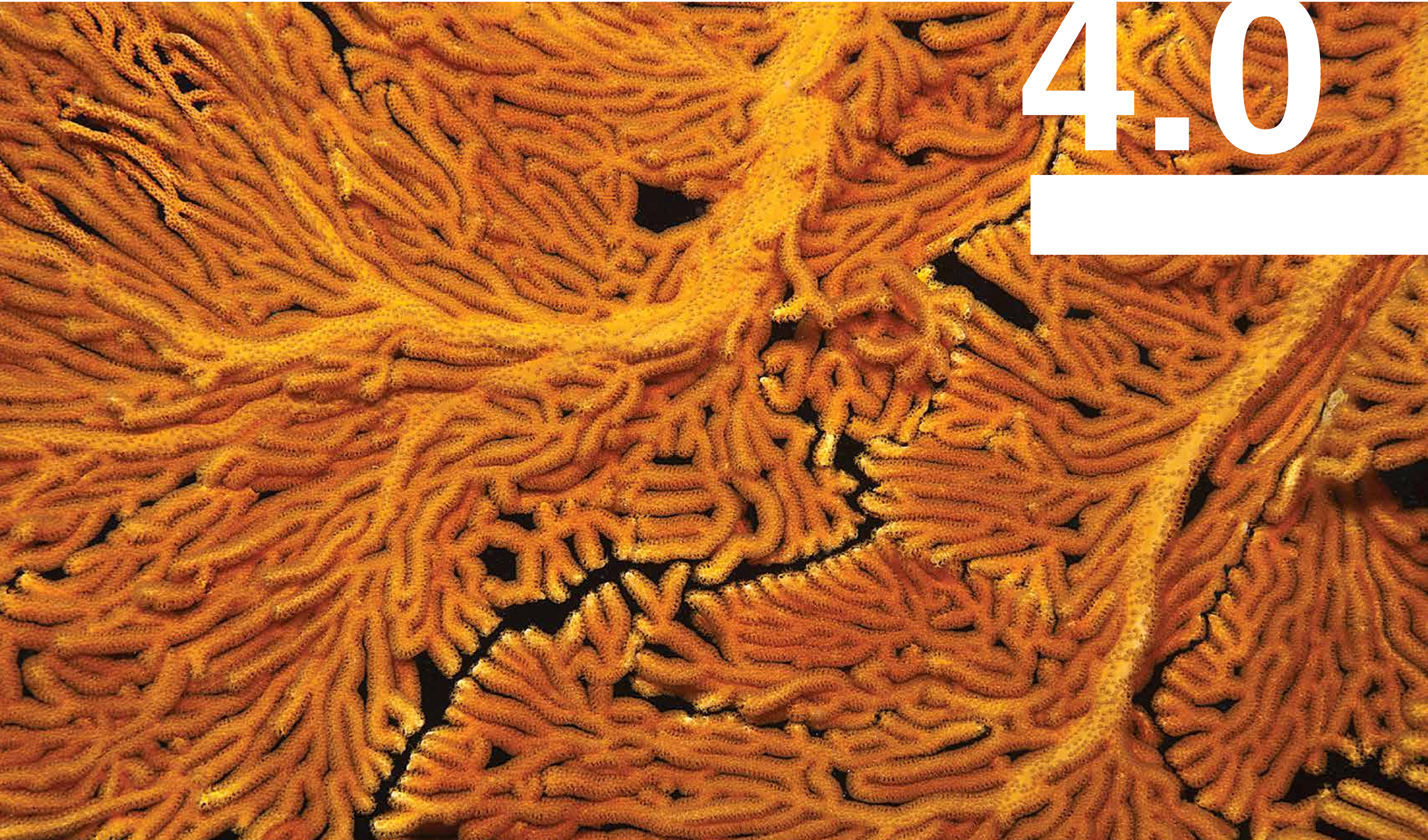
At most sites, the proportion of fish in each size category varied inversely with size. However, the patterns at Petit Guilbert, Gros Guilbert, and Merite differed from this pattern. Petit Guilbert and, to a lesser extent, Gros Guilbert were the only sites where fish in the 41-50 cm size category outnumbered fish in the 31-40 cm size category, with these categories making up 13.5% and 11.8% of the fish surveyed at this site, respectively. At Merite, fish in the 21-30 cm category outnumbered fish in the 11-20 cm category, making up 34.2% and 33.4% of the fish at this site, respectively. In fact, Merite had the highest proportion of fish in the 21-30 cm and 31-40 cm categories, with 25.4% of fish surveyed in the latter category. This may be related to the fact that Merite had the highest biomass of fish in the 3.6-4.0 trophic levels of all the sites surveyed.

Figure 22 THE RELATIVE SIZE DISTRIBUTION (%) OF SELECTED IMPORTANT FISH FAMILIES BASED ON THE TOTAL DENSITIES FROM 10 LOCATIONS IN NEW CALEDONIA. FAMILIES INCLUDED WERE: ACANTHURIDAE (18 SPECIES), CARANGIDAE (2), HAEMULIDAE (1), LETHRINIDAE (1), LUTJANIDAE (7), NEMIPTERIDAE (1), SCARIDAE (17), SERRANIDAE (9), AND SIGANIDAE (2). FISH WITH TOTAL LENGTHS BELOW 10 CM AND GREATER THAN 50 CM WERE EXCLUDED.



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



4.0

The observations collected on the GRE mission to New Caledonia were some of the most surprising and encouraging. In general, the benthic and fish communities of New Caledonia appear to be relatively healthy when compared with other coral reef communities around the world **(Figures 23-25)**. The data provided within this report are the most accurate data from the time of the expedition and provide important baseline data to aid in continued conservation efforts of these valuable reefs. However, it is worth noting that these reefs are dynamic and have been and will continue to be subjected to environmental impacts such as hurricanes, bleaching events, crown-of-thorns starfish (COTS) outbreaks, and marine diseases. The data collected on this mission will be critical for monitoring changes over time and adapting management plans to better conserve these habitats.

Prony Bay was the most puzzling region studied in New Caledonia. Generally, coral reef habitats with high nutrient and sediment input leads to an overabundance in algae and decrease in light[35], which, in turn, can make it difficult for juvenile corals to settle and grow. Prony Bay also has hydrothermal vents that bring in hyperalkaline water, with areas of very high pH values (pH 11)[11], which, in most cases, creates conditions which are hard for corals to grow. The shift in coral diversity and dominance is also interesting, leading us to believe these corals may be better adapted to living in these nontraditional conditions. It is possible that the enhanced turbidity[32,33], or the hydrothermal vents, are bringing in different nutrients that are contributing to abundant coral growth. A study looking at more acidified water has been conducted by Camp et al. (2017)[34] in the nearby Bouraké lagoon; however, a study looking at the impact of more basic water might help explain the high coral cover in Prony Bay. The higher coral cover may also be due to the reduced wave exposure, minimizing the external physical stress these corals experience, allowing them to persist in these harsher conditions. However, these reefs do continue to experience external stressors such as fresh water input and most recently COTS, which may cause widespread damage to the reefs. This wide range of explanations warrants a more in-depth study on the water chemistry, nutrient levels, stressors, and growth rates of the corals found on these reefs. Interestingly, the fish communities of Prony Bay boasted a lower mean species richness, fish density, and biomass when compared with the other sites. Due to the variability in our sites within Prony Bay, it is hard to discern the cause of this and should be investigated further.

Figure 23 GLOBAL COMPARISON OF FISH DENSITY OF COUNTRIES VISITED ON THE GRE.

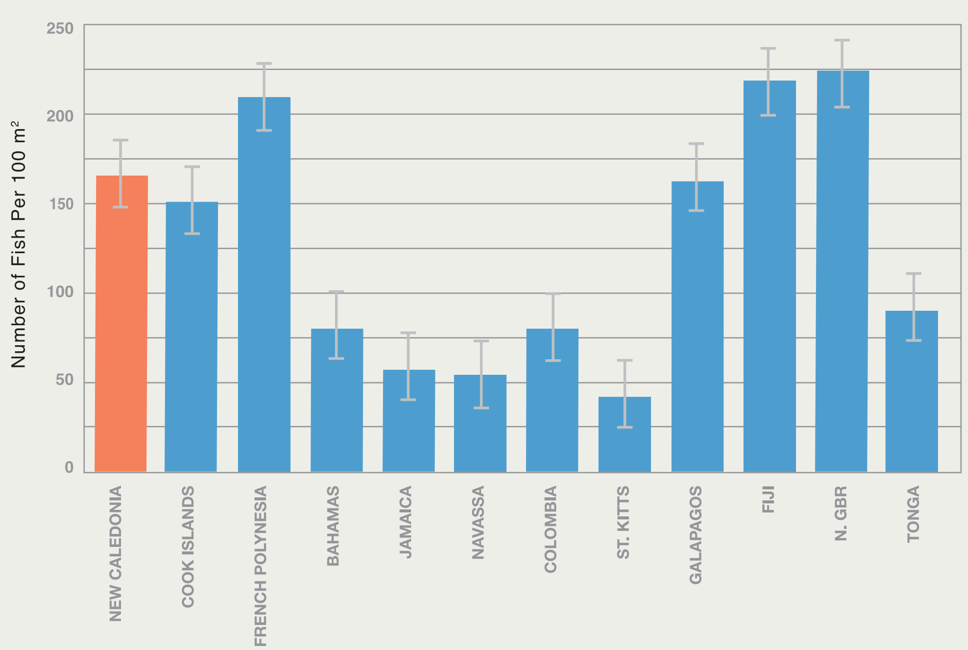
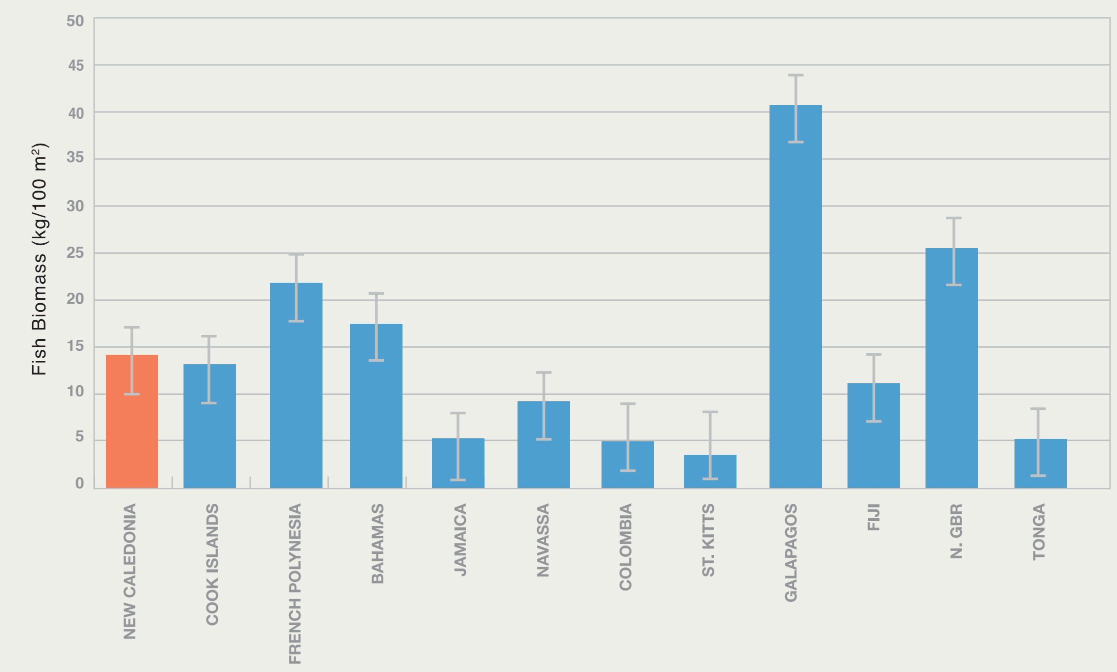


Figure 24 GLOBAL COMPARISON OF FISH BIOMASS OF COUNTRIES VISITED ON THE GRE.

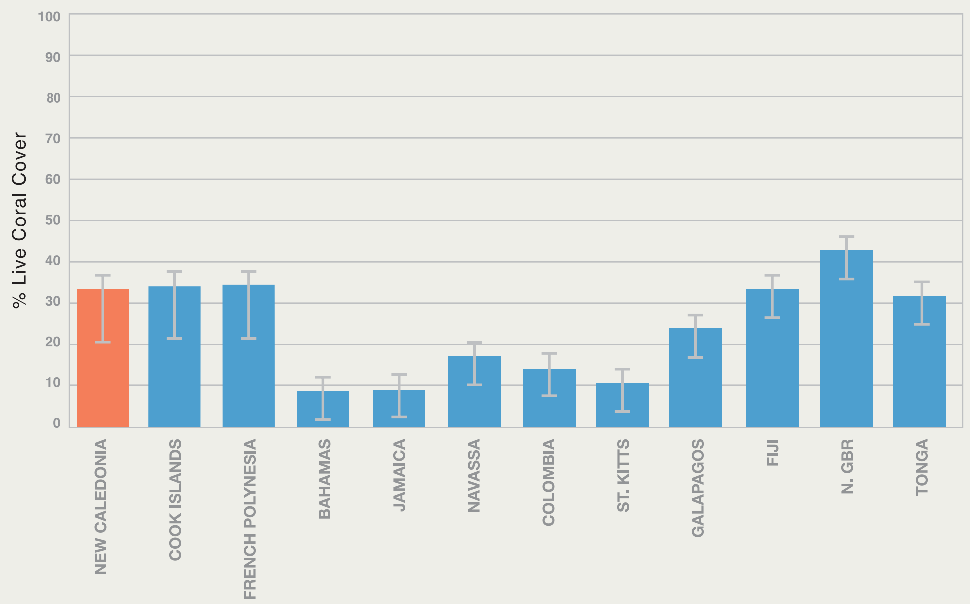


In general, fish populations in New Caledonia are very sound. However, there is an obvious distinction between the nearshore reefs of Prony Bay and Ile des Pins and the uninhabited and more isolated offshore reefs of the Entrecasteaux Atolls and Cook Reef. Prony Bay and Ile des Pins had lower mean fish species richness, fish density, and biomass than any of the northern atolls. The fish communities at these southern sites were also dominated by smaller fish and had relatively few apex predators in comparison with the offshore sites, indicating increased fishing pressure and a breakdown in the fish communities. This trend is likely due to the proximity of these sites to human population centers. Prony Bay, which had the least abundant fish community, is found adjacent to the main island, where the majority of New Caledonia's population lives. The fish community at Ile des Pins was slightly more diverse and populous, possibly because this small island has a much smaller permanent population; however subsistence fishing is prevalent, likely explaining the lower biomass and diversity within the fish communities found there.

The benthic community of Ile des Pins held the lowest live coral cover and had a higher percentage of fleshy algae present, likely being driven by the overall lower fish biomass and density found here. The dominance of small fish, and lack of larger grazers, may be contributing to the shift in the algal community away from CCA, toward fleshy algae; however, CCA was still the second most dominant alga observed, which is encouraging. Studies have shown that coral larvae specifically seek out CCA for settlement, and with the overgrowth of fleshy algae, such as turf and macroalgae, there is a lower probability of settlement success[36–38]. Due to the lower latitude of Ile

DISCUSSION

Figure 25 GLOBAL COMPARISON OF PERCENTAGE OF LIVE CORAL COVER AMONG COUNTRIES VISITED ON THE GRE.



des Pins, it is also possible that the fleshy macroalgae is more persistent due to the cooler water temperature when compared with the more northern sites[6]. The combination of the lower water temperature and poor fish communities may be driving this higher macroalgae presence.

The benthic and fish communities of the Entrecasteaux Atolls and Cook Reef boasted some of the highest coral cover, mean fish species richness, fish density, and fish biomass, with many large predators present. It appears that the greater distance of these reefs from Grande Terre has led to lower fishing pressure, allowing benthic and fish populations to flourish **(Figures 26-27)**. The fish and benthic communities of Pelotas stood out among the Entrecasteaux Atolls. It had the highest mean fish species richness, density, and biomass of all sites, as well as the highest live coral cover, and lowest algal cover observed. While all of the northern sites showed a high biomass of apex predators, this pattern was especially distinct at Pelotas. Merite also stood out in the Entrecasteaux Atolls due to the higher proportion of medium-sized fish found at this site than at others; however the benthic communities here had average live coral cover.

Figure 26 COMPARISON OF HUMAN POPULATION AGAINST MEAN FISH BIOMASS (KG/100 M²) FOR EACH LOCATION.

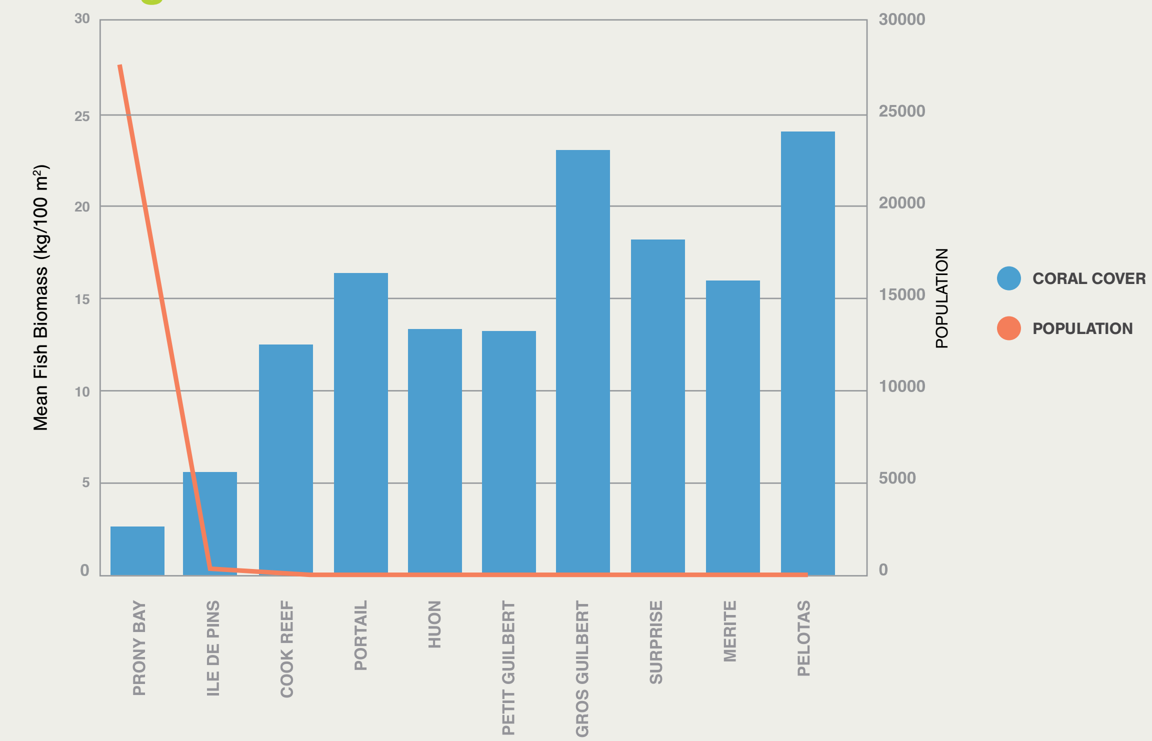
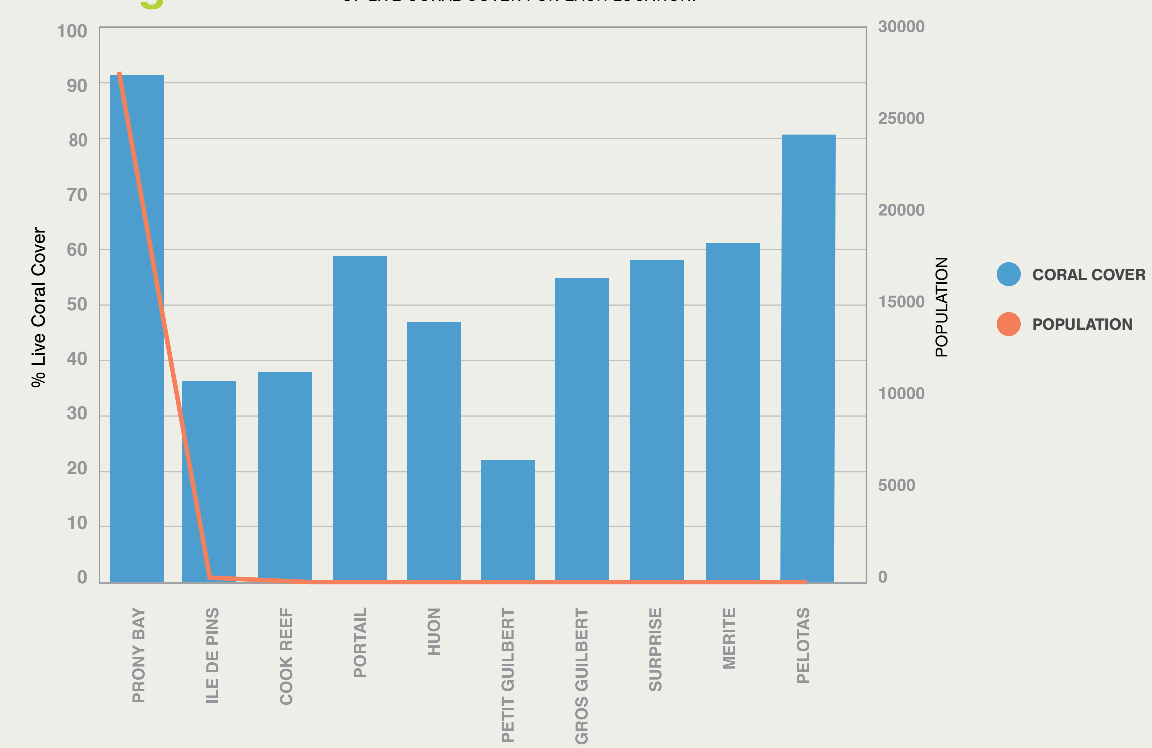


Figure 27 COMPARISON OF HUMAN POPULATION AGAINST PERCENTAGE OF LIVE CORAL COVER FOR EACH LOCATION.



5.0 CONSERVATION RECOMMENDATIONS

5.0

The conservation efforts of New Caledonia are some of the most advanced in the South Pacific and Coral Sea. New Caledonia's government, the Provinces, and local communities have displayed a clear commitment to the conservation of their reefs and fish communities through, in particular, the establishment of one of the largest Marine Protected Areas, *Le Parc Naturel de la Mer de Corail,* which is under the tutelage of the government. The data collected by KSLOF and New Caledonian scientists participating on the GRE shed a light on the areas where conservation efforts should be especially focused.

Le Parc Naturel de la Mer de Corail was designed to protect the natural and cultural heritage of New Caledonia, recognize sustainable and responsible use of resources, establish "good governance" of the marine resources, and develop a locally, regionally, and internationally integrated park to contribute to the conservation of marine habitats of the world[3] **(Figure 28)**. With these planned conservation efforts, it is apparent that there is hope that the reefs of New Caledonia will continue to flourish.

However, based on the findings of the GRE, it is evident that the nearshore fisheries are being impacted by the local communities of Grande Terre and Ile des Pins, primarily due to higher fishing pressure. These areas are not currently protected in *Le Parc Naturel de la Mer de Corail* and expansion of park management to include these is needed to protect the reef. Improved management at nearshore sites should address human impacts from several angles. The implementation of size limits and/or catch limits through improved legislation and enforcement may help the fish populations at the nearshore sites persist, particularly of the commercially important species, and could lead to larger numbers of large, predatory fish.

Areas where subsistence fishing is an integral part of community life, such as the case on Ile des Pins, will benefit greatly with harsher regulations on fishing and implementation of no-take and no-entry Marine Protected Areas. A study by Juhel et al. (2018)[39] in New Caledonia showed that human populations, regardless of protection level, have an impact the presence of large predatory fish such as sharks. An increase in no-entry zones will likely increase the presence of these fish. Reef sharks in particular play an important role in reef health and are considered indicator species for the health of reef fish communities. Increasing the number of no-entry zones will be vital in sustainably managing the reef fish around Ile des Pins.

> **Implementation of size or catch limits** could lead to **larger numbers of large, predatory fish** and **other commercially important species.**

In contrast, the fish populations at the Entrecasteaux Atolls and Cook Reef were very diverse and had high biomass of all trophic levels. The data collected on the GRE may prove to be valuable for the continued long-term monitoring of these no-take and no-entry zones. With increased stresses such as climate-change-induced bleaching events, ocean acidification, increase in hurricane frequency and intensity, and potential COTS outbreaks, these reefs and fish communities will become more susceptible to degradation. Numerous studies in the area have shown the value in protecting these atolls, including both marine and terrestrial habitats[8,39]. The larval coral and fish retention from these isolated reefs may prove to be vital for the long-term success of New Caledonia's reefs with the expected more frequent stressors.

The habitat maps (www.lof.org/maps) developed by KSLOF will help managers, scientists, and communities to work together to improve protection and management plans for the reefs of New Caledonia. Consultation of these maps will allow these groups to reassess current protocols and monitoring sites and better optimize management efforts. The maps will also be useful in developing new no-take and no-entry zones throughout New Caledonia. By combining the expertise of local scientific institutions, community members, and managers, as well as the research described in this report, the reefs of New Caledonia will continue to flourish and provide significant economic value to the community through sustenance fishing and tourism. The data collected in New Caledonia will also be included in ongoing resilience studies being undertaken by KSLOF and the University of Miami. These studies hope to highlight areas of reef resilience on a global scale and the inclusion of data of the unique habitats found in New Caledonia will surely strengthen our understanding of global reefs.

Figure 28 *LE PARC NATUREL DE LA MER DE CORAIL* WAS DESIGNED TO PROTECT THE NATURAL AND CULTURAL HERITAGE OF NEW CALEDONIA.

ACKNOWLEDGEMENTS

The Khaled bin Sultan Living Oceans Foundation is grateful for the assistance provided by our partners in New Caledonia in obtaining the permits for research and getting permission to work within each of the regions surveyed. We would like to express our thanks to Mr. Harold Martin, former Président du Government de la Nouvelle-Calédonie, Le Haut-Commissaire de la Republique en Nouvelle-Calédonie, Direction de l'Environment, *and* Direction du Développement Economique et de l'Environment *for granting us permission to sample and study the reefs of your country. KSLOF would like to especially thank Dr. Serge Andréfouët of the* Institut de Recherche pour le Développement *for his hard work in assisting with the planning and execution of this research mission.*

The research mission to New Caledonia 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 the research mission to New Caledonia through the involvement and partnerships by scientists from the following countries: New Caledonia, France, USA, New Zealand, Australia, Portugal, the Philippines, Indonesia, 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 Wellington, Florida Museum of Natural History, *Institut de Recherche pour le Développement*, GINGER-SOPRONER, AGGRA, Dive-In OCEAN Foundation, 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 research mission to New Caledonia benefited from Captain Steve Breen, Captain Patrick Walsh, 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 who 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 New Caledonia.

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

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Location	Site	Date	Longitude	Latitude	Reef Location	Exposure
Ile des Pins	Site 01	10/28/13	167.351	-22.665	lagoonal	leeward
Ile des Pins	Site 02	10/28/13	167.353	-22.652	lagoonal	leeward
Ile des Pins	Site 03	10/28/13	167.370	-22.648	lagoonal	leeward
Ile des Pins	Site 04	10/29/13	167.371	-22.496	fore reef	windward
Ile des Pins	Site 05	10/29/13	167.414	-22.515	fore reef	leeward
Ile des Pins	Site 06	10/29/13	167.301	-22.576	lagoonal	leeward
Ile des Pins	Site 07	10/30/13	167.564	-22.640	fore reef	windward
Ile des Pins	Site 08	10/30/13	167.549	-22.599	fore reef	windward
Ile des Pins	Site 09	10/30/13	167.449	-22.718	fore reef	windward
Ile des Pins	Site 10	10/31/13	167.196	-22.569	fore reef	windward
Ile des Pins	Site 11	10/31/13	167.208	-22.559	fore reef	leeward
Ile des Pins	Site 12	10/31/13	167.436	-22.655	lagoonal	protected
Ile des Pins	Site 13	10/31/13	167.309	-22.581	lagoonal	protected
Ile des Pins	Site 14	11/1/13	167.587	-22.719	fore reef	windward
Ile des Pins	Site 15	11/1/13	167.374	-22.701	fore reef	leeward
Ile des Pins	Site 16	11/1/13	167.542	-22.741	lagoonal	protected
Ile des Pins	Site 17	11/2/13	167.301	-22.459	fore reef	windward
Ile des Pins	Site 18	11/2/13	167.236	-22.486	fore reef	windward
Ile des Pins	Site 19	11/2/13	167.307	-22.640	lagoonal	protected
Ile des Pins	Site 20	11/3/13	167.533	-22.554	fore reef	windward
Ile des Pins	Site 21	11/3/13	167.442	-22.514	lagoonal	leeward
Prony Bay	Site 22	11/4/13	166.844	-22.314	bay	leeward
Prony Bay	Site 23	11/4/13	166.890	-22.366	bay	leeward
Prony Bay	Site 24	11/4/13	166.851	-22.352	bay	leeward
Pelotas	Site 25	11/6/13	163.235	-18.598	fore reef	windward
Pelotas	Site 26	11/6/13	163.212	-18.571	fore reef	leeward
Cook Reef	Site 27	11/7/13	163.573	-18.948	fore reef	windward
Cook Reef	Site 28	11/7/13	163.551	-18.871	fore reef	windward
Cook Reef	Site 29	11/7/13	163.485	-18.836	fore reef	leeward
Cook Reef	Site 30	11/8/13	163.559	-19.099	fore reef	leeward
Cook Reef	Site 31	11/8/13	163.505	-18.986	back reef	windward
Cook Reef	Site 32	11/8/13	163.414	-18.885	fore reef	leeward
Cook Reef	Site 33	11/9/13	163.682	-19.053	fore reef	windward
Cook Reef	Site 34	11/9/13	163.630	-19.061	channel	leeward
Cook Reef	Site 35	11/9/13	163.440	-18.877	back reef	leeward
Cook Reef	Site 36	11/10/13	163.531	-18.849	fore reef	windward
Cook Reef	Site 37	11/10/13	163.448	-18.852	back reef	leeward
Cook Reef	Site 38	11/10/13	163.435	-18.854	fore reef	leeward
Portail	Site 39	11/11/13	162.908	-18.508	back reef	windward
Portail	Site 40	11/11/13	162.889	-18.458	back reef	windward
Portail	Site 41	11/11/13	162.838	-18.463	fore reef	leeward
Huon	Site 42	11/12/13	163.872	-20.263	fore reef	leeward

Location	Site	Date	Longitude	Latitude	Reef Location	Exposure
Huon	Site 43	11/13/13	162.898	-17.887	fore reef	windward
Huon	Site 44	11/13/13	162.892	-17.936	fore reef	leeward
Huon	Site 45	11/13/13	162.906	-17.998	lagoonal	leeward
Huon	Site 46	11/14/13	162.828	-18.061	fore reef	leeward
Huon	Site 47	11/14/13	162.896	-17.978	fore reef	leeward
Huon	Site 48	11/14/13	162.916	-18.036	lagoonal	protected
Huon	Site 49	11/15/13	162.888	-18.233	fore reef	windward
Huon	Site 50	11/15/13	162.841	-18.196	fore reef	leeward
Huon	Site 51	11/15/13	162.816	-18.133	channel	leeward
Huon	Site 52	11/16/13	162.922	-17.920	fore reef	windward
Huon	Site 53	11/16/13	162.892	-17.951	fore reef	leeward
Huon	Site 54	11/16/13	162.932	-17.969	fore reef	windward
Petit Guilbert	Site 55	11/17/13	163.110	-17.999	fore reef	leeward
Petit Guilbert	Site 56	11/17/13	163.129	-18.015	fore reef	windward
Huon	Site 57	11/17/13	162.917	-17.969	back reef	leeward
Gros Guilbert	Site 58	11/18/13	163.089	-18.017	fore reef	leeward
Gros Guilbert	Site 59	11/18/13	163.075	-18.058	fore reef	windward
Huon	Site 60	11/18/13	162.966	-18.020	fore reef	windward
Surprise	Site 61	11/18/13	163.128	-18.506	fore reef	leeward
Surprise	Site 62	11/18/13	163.227	-18.497	fore reef	windward
Surprise	Site 63	11/18/13	163.231	-18.430	fore reef	windward
Merite	Site 64	11/19/13	163.028	-18.200	fore reef	windward
Merite	Site 65	11/20/13	163.017	-18.215	fore reef	windward
Surprise	Site 66	11/20/13	163.025	-18.465	fore reef	leeward
Surprise	Site 67	11/21/13	163.120	-18.313	fore reef	windward
Surprise	Site 68	11/21/13	163.040	-18.278	fore reef	windward
Surprise	Site 69	11/22/13	162.987	-18.300	channel	leeward
Surprise	Site 70	11/22/13	162.991	-18.396	channel	leeward
Surprise	Site 71	11/22/13	163.100	-18.497	fore reef	leeward
Portail	Site 72	11/23/13	162.842	-18.476	fore reef	leeward
Portail	Site 73	11/23/13	162.870	-18.519	fore reef	leeward
Surprise	Site 74	11/23/13	163.080	-18.463	lagoonal	protected
Pelotas	Site 75	11/24/13	163.253	-18.539	fore reef	windward
Pelotas	Site 76	11/24/13	163.187	-18.601	fore reef	leeward

APPENDIX 2 | PARTICIPANT LIST

Participant	Institution	Function
Phil Renaud	Khaled bin Sultan Living Oceans Foundation (KSLOF), former	Executive Director
Andy Bruckner	Khaled bin Sultan Living Oceans Foundation (KSLOF), former	Chief Scientist
Alex Dempsey	Khaled bin Sultan Living Oceans Foundation (KSLOF)	Director of Science Management
Allison Barrat	Khaled bin Sultan Living Oceans Foundation (KSLOF), former	Communications
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Badi Samaniego	University of the Philippines, Living Oceans Foundation Fellow	Fish Surveyor
Joao Monteiro	University of the Azores, Living Oceans Foundation Fellow	Symbiont Characterization
Anderson Mayfield	National Museum of Marine Biology and Aquarium, KSLOF Fellow	Coral Health
Steve Saul	University of Arizona	Habitat Mapping
Serge Andréfouët	*Institut de Recherche pour le Développement,* New Caledonia	Director of Research, Invertebrate Inventory
Cécile Fauvelot	*Institut de Recherche pour le Développement,* New Caledonia	Researcher, Geneticist
Antoine Gilbert	Project Manager, GINGER-SOPRONER	Scientific Diver
Ian Enochs	NOAA/University of Miami	Ocean Acidification
Ken Marks	Atlantic and Gulf Rapid Reef Assessment Program (AGRRA)	Photo Transects
Nathan Evans	Florida Museum of Natural History (FLMNH)	Invertebrate Taxonomy
Claude Payri	*Institut de Recherche pour le Développement,* New Caledonia	Director of Research, Phycologist
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Kate Fraser	Independent Contractor	Fish Surveyor
Nick Cautin	Dive Safety Officer	Diving Operations

NOTES

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