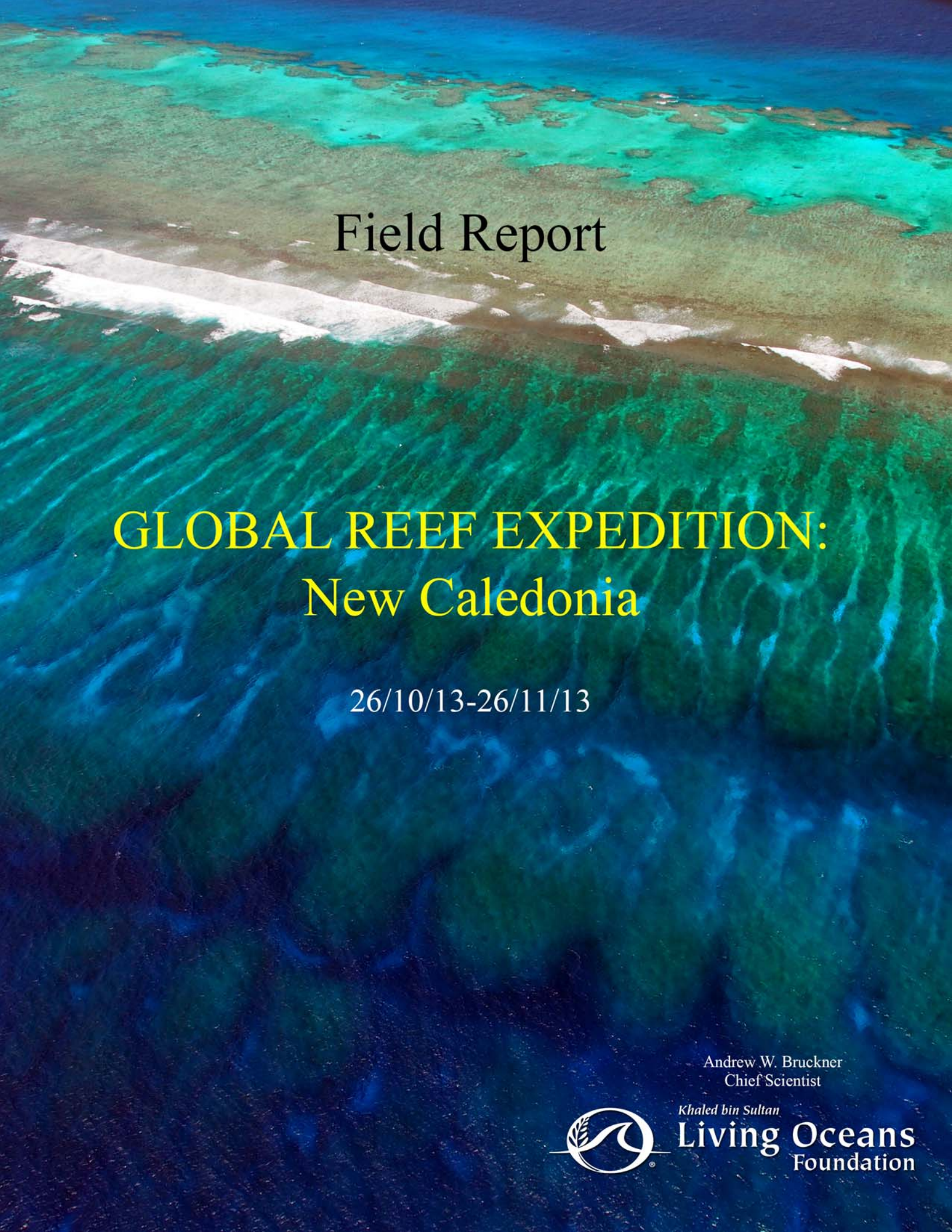

Field Report

GLOBAL REEF EXPEDITION:
New Caledonia

26/10/13-26/11/13

Andrew W. Bruckner
Chief Scientist

Khaled bin Sultan
Living Oceans
Foundation

Front cover: Spur and groove habitat on the fore reef of Cook Reef. Photo by Andrew Bruckner.

Back Cover: A shallow fore reef community off the leeward side of Surprise. Photo by Andrew Bruckner.

Khaled bin Sultan Living Oceans Foundation
8181 Professional Place
Landover, MD, 20785 USA
Philip G. Renaud, Executive Director

http://www.livingoceansfoundation.org

This report was developed as one component of the Global Reef Expedition: New Caledonia research project to meet one of the requirements of the research permit approved by Le Haut-Commissaire de la Republique en Nouvelle-Caledonia Ref. 157/CMRT issued 9 October, 2013; Le Gouvernement de la Nouvelle-Caledonie, No. 2013-2733/GNC issued 1 Oct 2013 and N° 2013-3329/GNC issues 26 November 2013; and Presidence, Secretariat General de la Province Sud, No. 2421-2013/ARR/DENV issued 6 Nov 2013. The North Province granted authorisation to conduct research on Cook Reef through IRD.

Oct. 15, 2014.

Citation: Global Reef Expedition: New Caledonia. Field Report. Bruckner, A.W. (2014). Khaled bin Sultan Living Oceans Foundation, Landover MD. pp. 38.

The Khaled bin Sultan Living Oceans Foundation (KSLOF) was incorporated in California as a 501(c)(3), public benefit, Private Operating Foundation in September 2000. KSLOF headquarters are in Washington DC. The Living Oceans Foundation is dedicated to the conservation and restoration of oceans of the world, and champions their preservation through research, education, and a commitment to *Science Without Borders*®.

For more information, visit http://www.lof.org and http://www.globalreefexpedition.com. Also on Facebook: https://www.facebook.com/livingoceansfoundation Twitter: https://twitter.com/LivingOceansFdn

EXECUTIVE SUMMARY

Between, 26 October, 2013 – 26 November, 2013, the Khaled bin Sultan Living Oceans Foundation conducted a research mission to New Caledonia as part of the Global Reef Expedition. The research focused on coral reefs in four locations, Ile des Pins, Prony Bay, Cook Reef and the atolls of Guilbert, Huon, Merite, Neulka, Pelotas, Portail and Surprise. The project was conducted in partnership with the Institut de Recherche pour le Développement (I.R.D.), with involvement of scientists from Nova Southeastern University, University of the Azores, University of the Philippines, NOAA/University of Miami, Atlantic and Gulf Rapid Reef Assessment Program (AGRRA), Florida Museum of Natural History (FMNH), and the National Museum of Marine Biology and Aquarium (Taiwan). The objectives of the mission were to:

1) Identify and characterize shallow marine habitats and develop habitat and bathymetric maps;
2) Evaluate the composition, structure and health of coral reefs using a standardized assessment protocol;
3) Assess the diversity, abundance and population structure of fishes, corals and other invertebrates, and algae, including commercially valuable species;
4) Evaluate the effects of environmental stressors on coral health and subcellular changes through biomarker expression;
4) Assess the prevalence and impacts of diseases and potential causative agents through histology.
5) Measure ocean chemistry (pH) and effects on coral growth;
6) Characterize the types of symbionts in reef building corals and variations in their photosynthetic efficiency under different environmental conditions;
7) Characterize the diversity, evolutionary relationships between populations, and effects of the environment on green algae (the group Bryopsidales; *Caulerpa, Halimeda* and *Codium*) and the gelatinous red algae (Halymeniales) in Ile de Pins (I.R.D.);
8) Examine the genetic diversity of giant clams (I.R.D.);
9) Characterize and catalogue the taxonomy, biogeography, and systematics of invertebrates found in shallow marine environments (I.R.D. and F.M.N.H.);
10) Investigate the extent of auto- and heterotrophy in different New Caledonian coral species exposed to various environmental conditions and determine the potential food sources for these species across varying scales of human impacts (I.R.D.);
11) Evaluate the population status of commercially important sea cucumbers (I.R.D.); and
12) Identify and characterize coral reef habitats of Prony Bay (I.R.D.).

Groundtruthing: A total of 2662 sq. km of WorldView 2 satellite imagery was acquired. To characterize shallow marine habitats, 593 videos (drop cameras) and 2,982,073 depth soundings were taken across study areas, covering a distance of 492 km.

Coral Reef Assessments: Surveys were conducted in four regions of New Caledonia at 76 different sites. A single dive was performed in each location. In total, 432 fish transects, 432 benthic surveys, 176 coral assessments and 216 phototransects were completed in 76 sites in the following locations: Ile des Pins, Prony Bay, Cook Reef and the atolls of Guilbert, Huon, Merite, Neulka, Pelotas, Portail and Surprise, with assessments undertaken from 5-30 m depth when possible. Over 24,000 corals, 4 cm diameter and larger, were measured and examined in situ. A total of 181 species of fish were recorded along 30 m transects in Ile des Pins and Prony Bay, 80 on Cook Reef, and 232 on the northern atolls. Sea cucumbers were assessed at 31 sites in the northern atolls, 28 on the fore reef and 8 in the lagoon.

Coral Reef Research:

- A total of 99 sediment samples were collected in 8 locations.
- A total of 144 samples of *Pocillopora damicornis* were collected from 9 locations to assess expression of biomarkers of stress.
- 566 biopsies were taken from giant clams (*Tridacna maxima* , *Hippopus hippopus* and other species) giant clams for DNA analysis and further population genetic and phylogeography analysis..
- 335 samples of gelatinous red algae, brown algae and green algae were collected in Ile des Pins.
- A total of 674 species of invertebrates, represented by 113 molluscs, 206 echinoderms, 331 crustaceans and 14 other invertebrates were collected in the four regions.

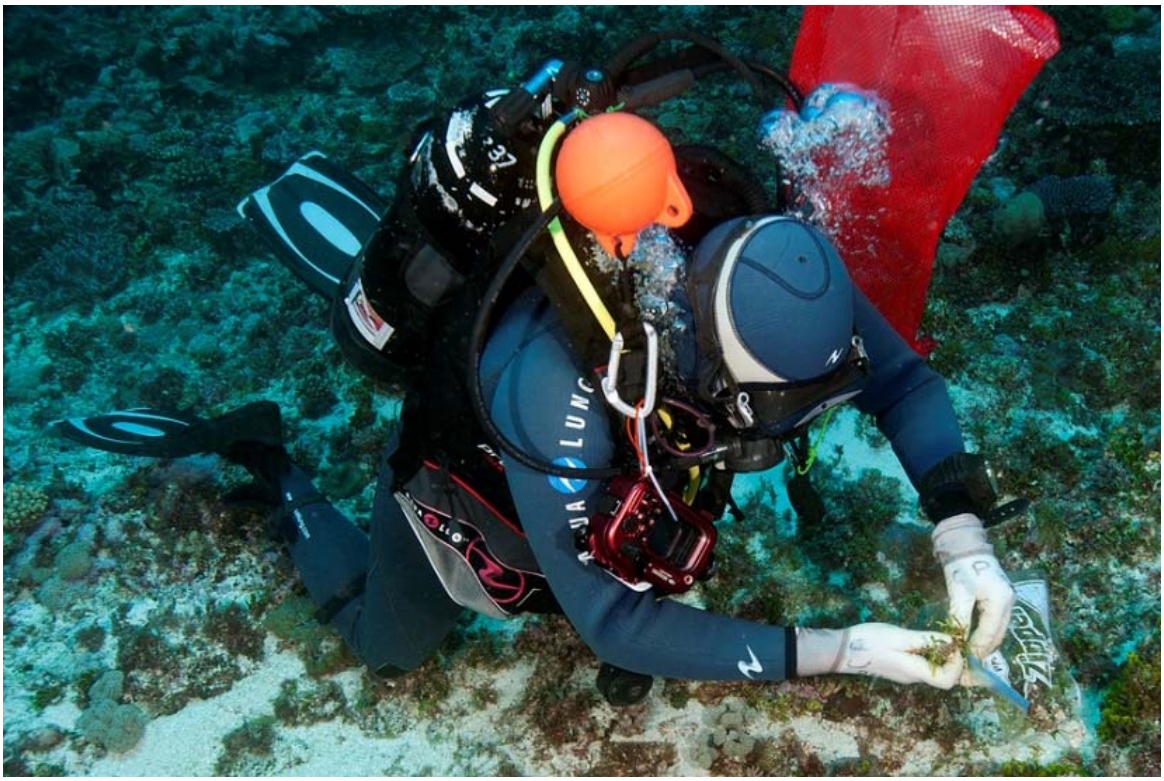

Fig. 1, Sampling algae on a reef off Ile des Pins.

Summary of general findings

Ile de Pins

- Reefs supported a high diversity of corals and algae, with communities containing coral and algal species found in cold environments as well as warmer environments.
- Most sites were dominated by algae with relatively low coral cover. Algae consisted of both thick mats of macroalgae and thick turfs. *Asparagopsis* was the most common red algae, found at depths ranging from 2-15m.
- High densities of damselfish and damselfish algal lawns were noted.
- The stony coral *Leptoria phyrigia* was one of the most abundant corals, and it was rare or absent from most other locations in New Caledonia.
- Fish assemblages appear to be strongly influenced by the type of habitat. In areas of high macro algae and low visibility, there were fewer fish and less variety. Sites with high physical complexity, good coral cover with less macro algae, and high currents areas had significantly higher abundances and higher diversity of reef fishes.
- In high relief coral dominated areas, carnivores such as groupers (*Plectropomus leopardus*, *P. laevis, Variola louti*), sharks (*Carcharhinus amblyrhnchos*, *Triaenodon obesus*), snappers (*Lutjanus bohar, Macolor niger, L. fulviflamma, L. kasmira*), and benthic carnivores such as sweetlips (*Plectorhinchus chaetodonoides*), and napoleon wrasse (*Cheilinus undulatus*) were common.
- In shallow areas with high macroalgae (*Caulerpa* sp.) large herbivores and planktivores such as drummers (*Kyphosus* sp.), surgeonfish and unicornfish (*Naso tonganus*, *Naso brevirostris*), and rabbitfish (*Siganus spinus*) were abundant.

Fig. 2. One of the dominant corals in Ile des Pins, *Leptoria phyrigia.*

Prony Bay

- Reefs were characterized by unique species assemblages and habitats not found elsewhere in New Caledonia. Prony Bay is a large sheltered bay surrounded by hillsides with high-metal concentration in the soils. There is considerable land erosion and run-off from several small rivers that discharge within the bay, and the seaward side is affected by heavy wave action and currents. During periods of rainfall here is often a freshwater layer, and mixing by waves and currents can cause declines in salinity that affect shallow coral communities. Prony Bay contained fringing reefs, many with steep slopes, reef communities adjacent to small islands within the bay, and also communities on the seafloor affected by geothermal vents. Freshwater, sedimentation and high wave action and currents structure the coral communities, such that only the most tolerant species that are adapted to these harsh conditions are able to flourish.
- The highest diversity of coral species in New Caledonia, with dense monospecific assemblages of plating *Leptoseris,* thickets of bottlebrush Acroporids, large spheroids of Porites cylindrica, reef slopes with overlapping sheets of Merulina, extensive thickets of *Anacropora* in shallow water, Large to medium table Acroporids and many other taxa.
- Several coral species were not found elsewhere in New Caledonia, including: *Cantharellus jebbi; Madracis kirbyi, Cyphastrea japonica, Trachyphyllia, Caulastrea,* and *Leptaseris gardeneri*.
- Fish were generally few at depths exceeding 10m. There was higher density of fish at shallower depths (less than 8m). Parrotfish were the dominant group. Several groupers (*Plectropomus leopardus*) were noticeably pale in coloration.

Fig. 3. Prony Bay supported unique habitats with dense monospecific assemblages of corals.

Cook Reefs

- Several unique species of corals including*: Favites chinensis, Zoopilus, Hydnophora grandis,* and *Pocillopora kelleri*.
- Crown of thorns sea stars were noted on several reefs.
- Storm damage was prevalent and many windward reefs were dominated by large rubble fields.
- Soft corals were colonizing a large proportion of open substrate
- The coral framework was constructed of*Porites lobata*, however large burrowing bivalves seemed to have eroded parts of the reef making the substrate somewhat brittle and incongruent.
- Large calcified *Halimeda* flakes were concentrated in small pockets or mounds. This could potentially be an indication of a high carbonate budget being produced on the fore reef slope.
- Dense stands of Acropora robusta with 30-60% partial mortality and considerable signs of damselfish stress. Large numbers of damselfish present among the matrix community of dead staghorn coral.
- The highest fish diversity and abundance recorded during this mission was noted on Cook Reef. There was an abundance of sharks (*Carcharhinus amblyrhynchos*), huge groupers (*Plectropomus laevis*, *Epinephelus lanceolatus*, *Epinephelus malabaricus*), large parrotfish (*Chorurus microrhinos*), snappers (*Macolor macularis*, *Macolor niger*, *Lutjanus bohar*), unicorn and surgeonfish (*Naso caesius*, *Naso tonganus*) schools of jacks (*Caranx ignobilis, Caranx sexfasciatus*), barracuda (*Sphyraena qenie*), tuna and mackerel (*Gymnosarda unicolor*), and napoleon wrasse (*Cheilinus undulatus*). In particular, large top predators (tiger shark, silvertip and grey reef sharks, and large groupers), were observed in NCCR 37 along the wall.

Fig. 4. White tip shark (*Triaenodon obesus*) on Cook Reef.

Northern Atolls

- Many sites had high coral cover with mixed communities of plating *Echinophyllia*, bottlebrush Acroporids, and *Pavona maldivensis.*
- Lagoonal sites exhibited a *Porites* framework colonized by many species of corals. Big stands of spindle Acroporids, foliose *Turbinaria* and *Porites cylindrica* were present.
- Crown of thorns (COTS) damage and active feeding by COTS was recorded on Guilbert , Pelotas and Huon. This is unusual as these atolls are remote and have no emergent land and are therefore not susceptible to nutrient run off.
- Large table Acroporids on Surprise had a high prevalence of white syndrome and yellow band disease was also noted among acroporids on these reefs.
- Large mats of encrusting leather corals covered substantial portion on top of pinnacles.
- The structure of fish assemblages varied widely across sites.
- Pelotas had a high fish diversity on deep transects.
- Huon was notable for its grey reef sharks (*Carcharhinus amblyrhynchos*), whitetip reef sharks (*Triaenodon obesus*) bumphead parrotfish (*Bolbometopon muricatum*), Napoleon wrasse (*Cheilinus undulatus*), and unicornfish (*Naso caesius, Naso hexacanthus*) were common. Sites 51 and 53 also had an exceptionally high abundance and biomass of fish snappers (*Lutjanus gibbus, Macolor niger, Lutjanus bohar*), surgeonfish (*Acanthurus grammoptilus, Naso caesius*), steephead parrotfish (*Chlorurus microrhinos*), bumphead parrotfish (*Bolbometopon muricatum*), damselfish (*Chromis margaritifer*), Napoleon wrasse (*Cheilinus undulatus*), barracuda (*Sphyraena qenie*), grey reef sharks (*Carcharhinus amblyrhynchos*), and white tip sharks (*Triaenodon obesus*).
- Guilbert had high fish diversity and abundance of important target fish such as sharks, napoleon wrasse, snappers and groupers
- Surprise, Merit and Porteon also exhibited high diversity, and a high abundance of top predators (grey reef shark, silvertip shark, white tip shark, snappers and groupers).

Fig. 5. Fragile foliaceous and branching corals were common in lagoonal sites of the northern atolls. Shown here is *Turbinaria* and *Acropora*.

Introduction

New Caledonia, a special collectivity (a former territory under special status) of France, is located in the southwest Pacific about 1200 km from Australia. This archipelago encompasses an area of over 1.74 million km^2, which includes 18,575 km^2 of land area and an estimated 7,300 km^2 of shallow reef and associated habitats. Most of the land area is made up of the main island of Grande Terre (16,372 km^2), the Loyalty Islands to the east (1,981 km^2), and Ile des Pins to the southeast (152 km^2), Chesterfield Islands and Bellona Atoll to the west, and a number of smaller islands and atolls to the north. Part of the archipelago sits on a shallow shelf platform which forms the northern end of Zealandia, a fragment of the ancient Gondwana super-continent separated from Australia some 60-85 million years ago.

The Global Reef Expedition focused on four main regions in New Caledonia, Ile des Pins, Prony Bay, Cook Reef and the northern atolls. Ile des Pins, south of Noumea, has a double barrier reef encircling the island, many smaller islands surrounded by coral reefs, extensive lagoonal reef systems, and Nokanhui Atoll at the southeast tip. The underwater fauna and flora found underwater is unique as it sits at the confluence of cold, southern Antarctica water and northern tropical waters. Prony Bay, at the southern end of Grande Terre, is surrounded by stark red hillsides with scrubby vegetation marred by nickel mining operations. As the bay is heavily laden with silt, the coral communities here are adapted to these extreme conditions and consist of species absent from most other locations. Cook Reef, located north of Grande Terre. It forms part of the world's second longest barrier reef (over 1200 km in length), which extends from the northern end of Ile des Pins, surrounds Grande Terre, and encloses a massive (40,000 km^2) shallow lagoon to the north. The lagoon is a World Heritage site, named for its natural history, exceptional diversity of animals and plants, a continuum of habitats from mangroves to seagrasses, and a diverse concentration of reef structures. Cook Reef has an extensive spur and groove system surrounding lagoonal reef habitat. The seven northern atolls, Pelotas, Portail, Surprise, Huon, Guilbert and Merite are all low-lying with extensive fore reef communities around their perimeter that drops abruptly to deep water, fairly wide reef flats, and well developed lagoonal patch reefs and fringing reefs. These atolls have very little emergent land – the largest is a 3 km strip of sand at Huon. This beach is home to large populations of birds and one of the largest turtle nesting sites in New Caledonia.

The research mission included three primary components, habitat mapping, coral reef surveys and assessments, and coral reef research. Targeted research was conducted on coral disease, coral symbionts, the health of corals and the effects of ocean chemistry (pH) on coral growth, and samples of coral tissue, skeleton and coral symbionts were collected. Additional work by IRD focused on giant clams genetics, sea cucumber population assessments, algae taxonomy and

diversity, coral nutrition mode, and invertebrate biodiversity. All research was conducted from the M/Y Golden Shadow and multiple smaller support (dive) vessels.

Table 1. Research Schedule, New Caledonia.

Sat	26	Arrive in New Caledonia 9:30 AM	
Sun	27	Press conference. Scientists arrive in afternoon. Depart in evening. Overnight to Isle de Pins	Distance from Noumea to Ile des Pins is 110' (9hrs)
Mon	28	Pins	
Tue	29	Pins	
Wed	30	Pins	
Thu	31	Pins	
Fri	1	Pins	
Sat	2	Pins	
Sun	3	Neulka	
Mon	4	Prony Bay	Change-out of scientists
Tue	5	Transit to Cook Reef	Transit distance apprx 300'
Wed	6	Cook Reef	
Thu	7	Cook Reef	
Fri	8	Cook Reef	
Sat	9	Cook Reef	
Sun	10	Pelotas	
Mon	11	Portail	
Mon	11	Overnight transit to Poum	19 hours total
Tue	12	Transit to Surprise	Full day, No diving
Wed	13	Surprise	
Thu	14	Surprise	
Fri	15	Surprise	
Sat	16	Surprise	
Sun	17	Surprise	
Mon	18	Merite/Guilbert	
Tue	19	Merite/Guilbert	
Wed	20	Merite/ Guilbert	
Thu	21	Huon	
Fri	22	Huon	
Sat	23	Huon	
Sun	24	Huon	
Mon	25	Transit back to Noumea	340' (approx 31hrs)
Tues	26	Scientists disembark (Noumea)	10:15 AM flight

Research Completed

1. Habitat mapping and groundtruthing:

Using multispectral satellite imagery obtained from DigitalGlobe WorldView 2 satellite, high resolution bathymetric maps and habitat maps are being created for shallow coral communities. Groundtruthing efforts necessary to develop these maps focused on aerial surveys of each island's coastline and adjacent shallow marine habitat, continuous bathymetry measures, drop camera analysis, characterization of sediment and hard substrates and habitat features using two acoustic sub-bottom profiling equipment (Stratabox and Hydrobox) and fine scale photo-transect surveys.

Satellite imagery

A total of 2662 sq km of WorldView 2 (8 band) satellite imagery was acquired for this project (Table 2). The satellite images had a spatial resolution of 2-m by 2-m (i.e., each pixel covers a 4-m^2 area) enabling real-time navigate in the field to locate features of interest and to avoid dangerous features (e.g., emergent reefs). In order to navigate, the team used the scenes in conjunction with a differential GPS device (dGPS). The imagery is being used with ground truth data to create bathymetric and benthic habitat maps.

Benthic Video

An underwater video camera attached to a cable, called a drop-cam, was used to gather video on the benthic composition at each survey site. At each point, the drop-cam was held from the survey boat enabling it to 'fly' along the sea floor as it records video for 15 to 60 seconds. During this time, the laptop operator watched the video in real-time and guided the drop-camp operator to raise or lower the camera. In this manner, we were able to prevent damage to marine life. The video was recorded on a ruggedized laptop, and the geographic position, time, date, boat heading, and boat speed were burned into the video. Drop-cam deployment was limited to depths above 40 m due to the limited length of the tether cable (50 m). The acquired videos are being used to create the benthic habitat maps by providing the necessary information for the development of a habitat classification scheme and training of classification models. A minimum of 30 drop-cam videos were gathered per day, with 593 collected over the duration of the mission.

Acoustic depth soundings

Depth soundings were gathered along transects between survey sites using Hydrobox, a single-beam acoustic transducer, developed by Syqwest. The instrument emits 3 pings per second. Depths were estimated based on the time the return-pulse's reaches the sounder's head. Geopositional data were simultaneously acquired by the dGPS unit. The estimated depth values and their geographic location were recorded in the ruggedized laptop. The soundings were used to train a water-depth derivation model, which is based on the spectral attenuation of light in the water column. The final topographic map will have the same spatial resolution as the satellite imagery. An average of 100,000 acoustic depth soundings was gathered during a full work day, with 2,982,073 collected over the duration of the mission.

Site	Imagery (sq km)	No. dropcams	No. depth soundings	Track length (km)
Huon	415	145	805042	126.7168
Guilbert	47	32	180062	24.207
Merite	22	21	101805	19.299
Portail	89	35	153757	28.691
Pelotas	62	30	110547	20.62
Surprise	611	92	481586	82.0073
Neulka	25	15	244747	11.372
Pins	841	179	713767	142.264
Cook Reef	550	44	190760	36.994
Total	**2662**	**593**	**2982073**	**492.1711**

Table 2. Summary of groundtruthing datasets including total area of satellite imagery acquired, number of deployments of the drop camera, number of depth soundings and total distance covered by the groundtruthing team.

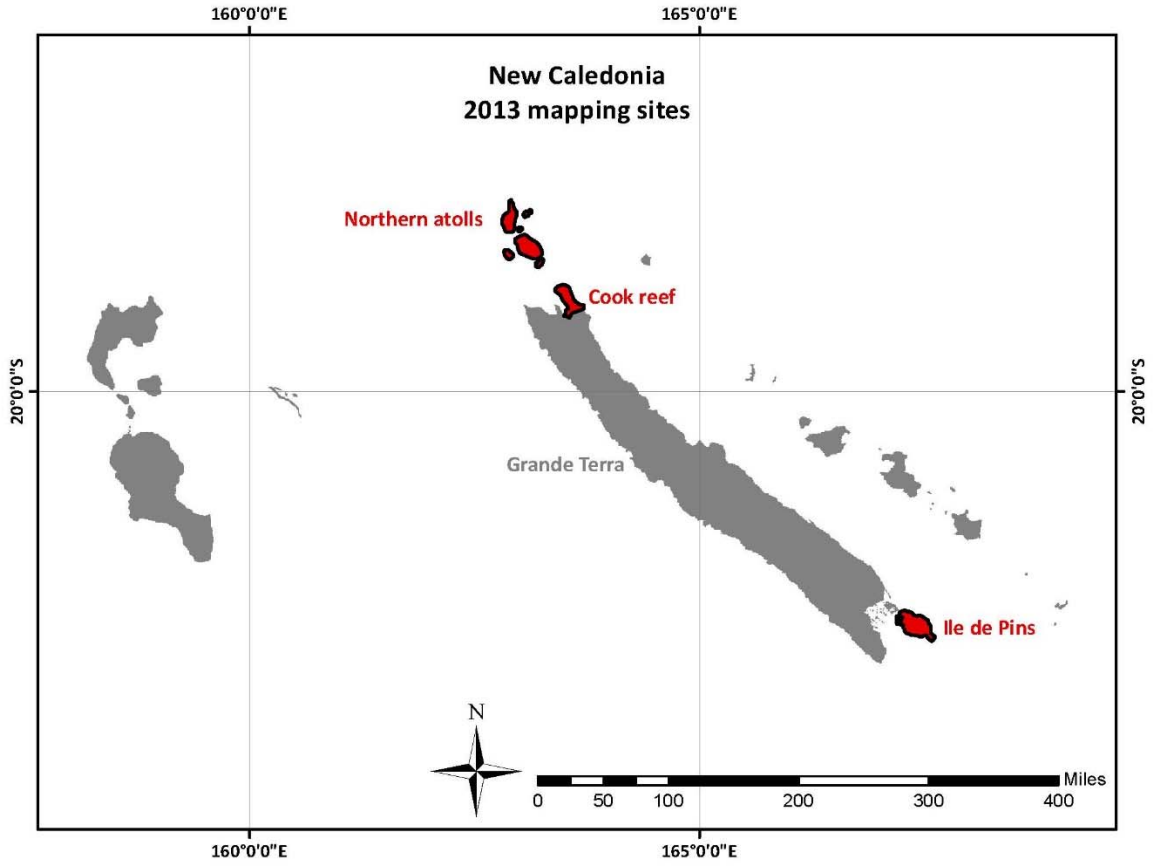

Fig. 6. Areas targeted for habitat mapping (shown in red).

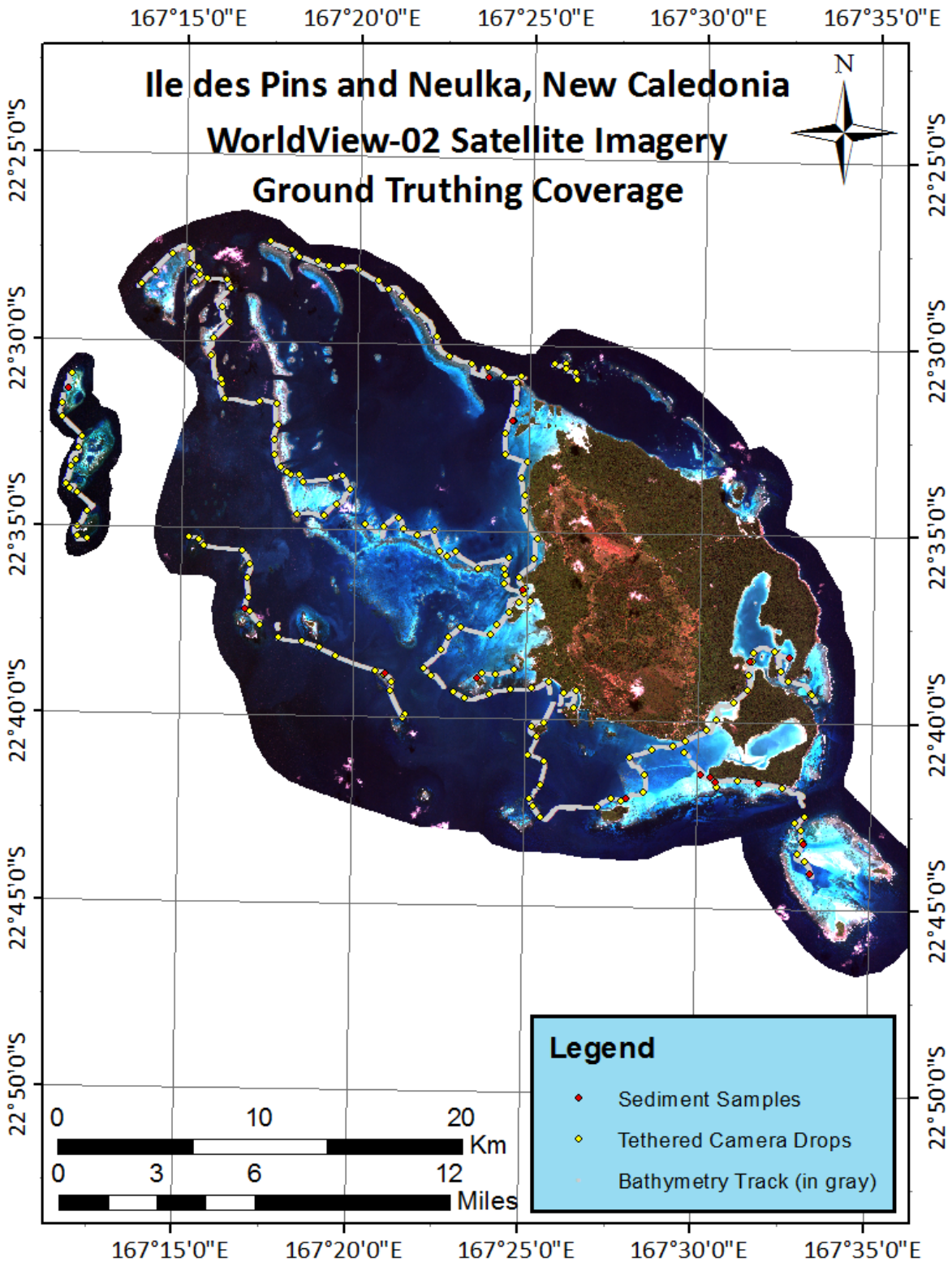

Fig. 7. Groundtruthing track and drop camera deployments around Pins and Neulka.

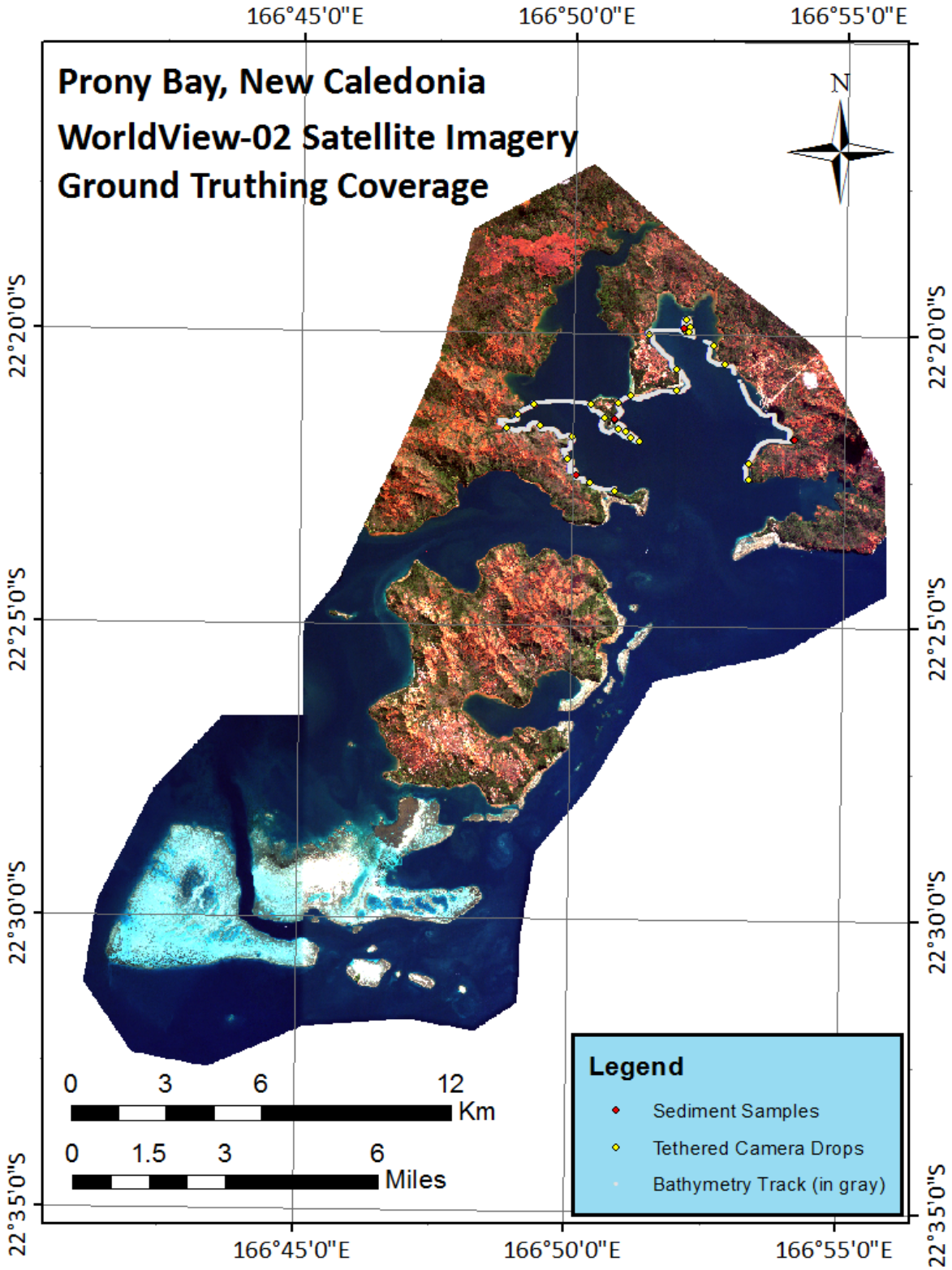

Fig. 8. Groundtruthing track and drop camera deployments around Prony Bay.

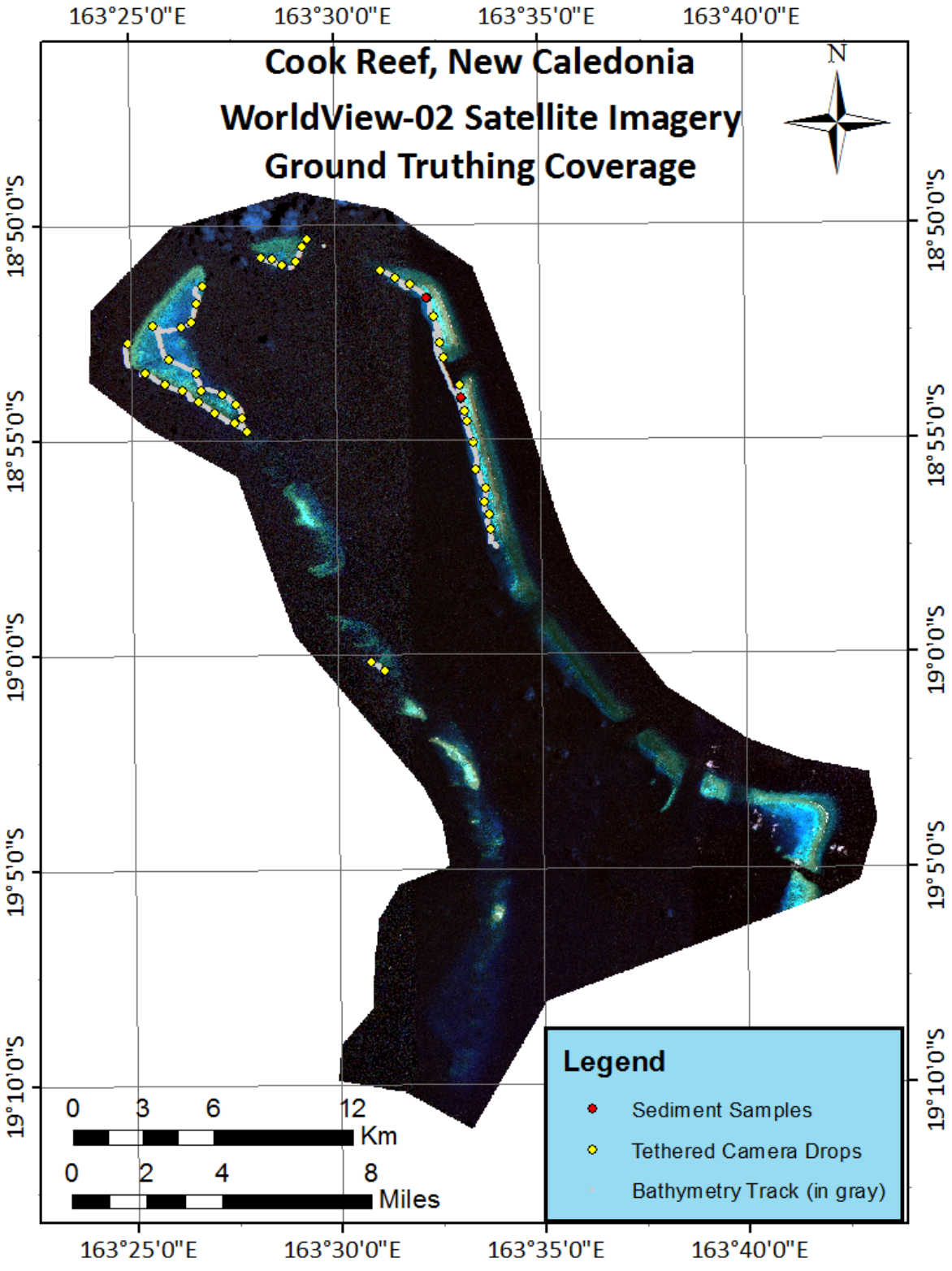

Fig. 9. Groundtruthing track and drop camera deployments around Cook Reef.

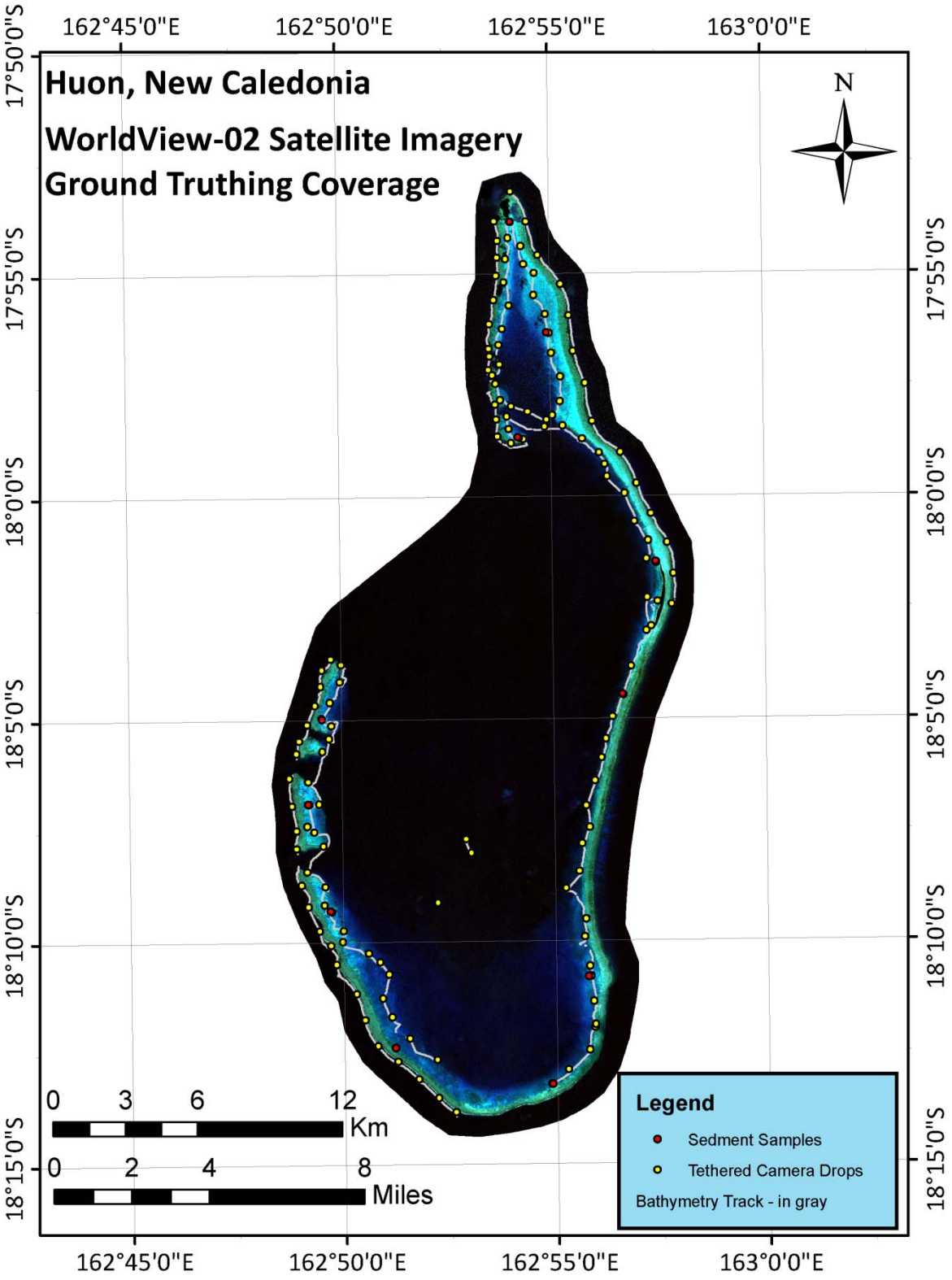

Fig. 10. Groundtruthing track and drop camera deployments around Huon.

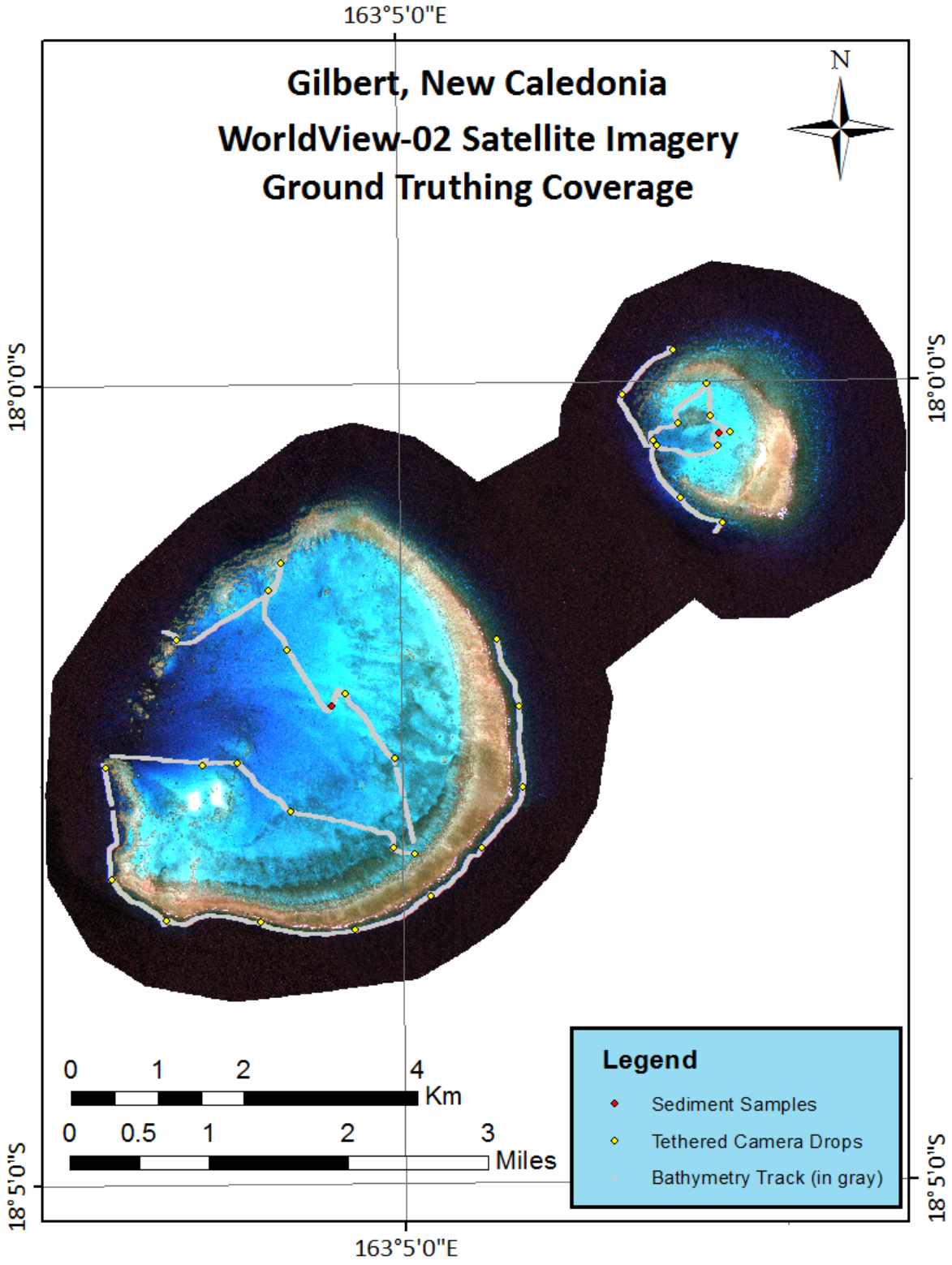

Fig. 11. Groundtruthing track and drop camera deployments around Guilbert.

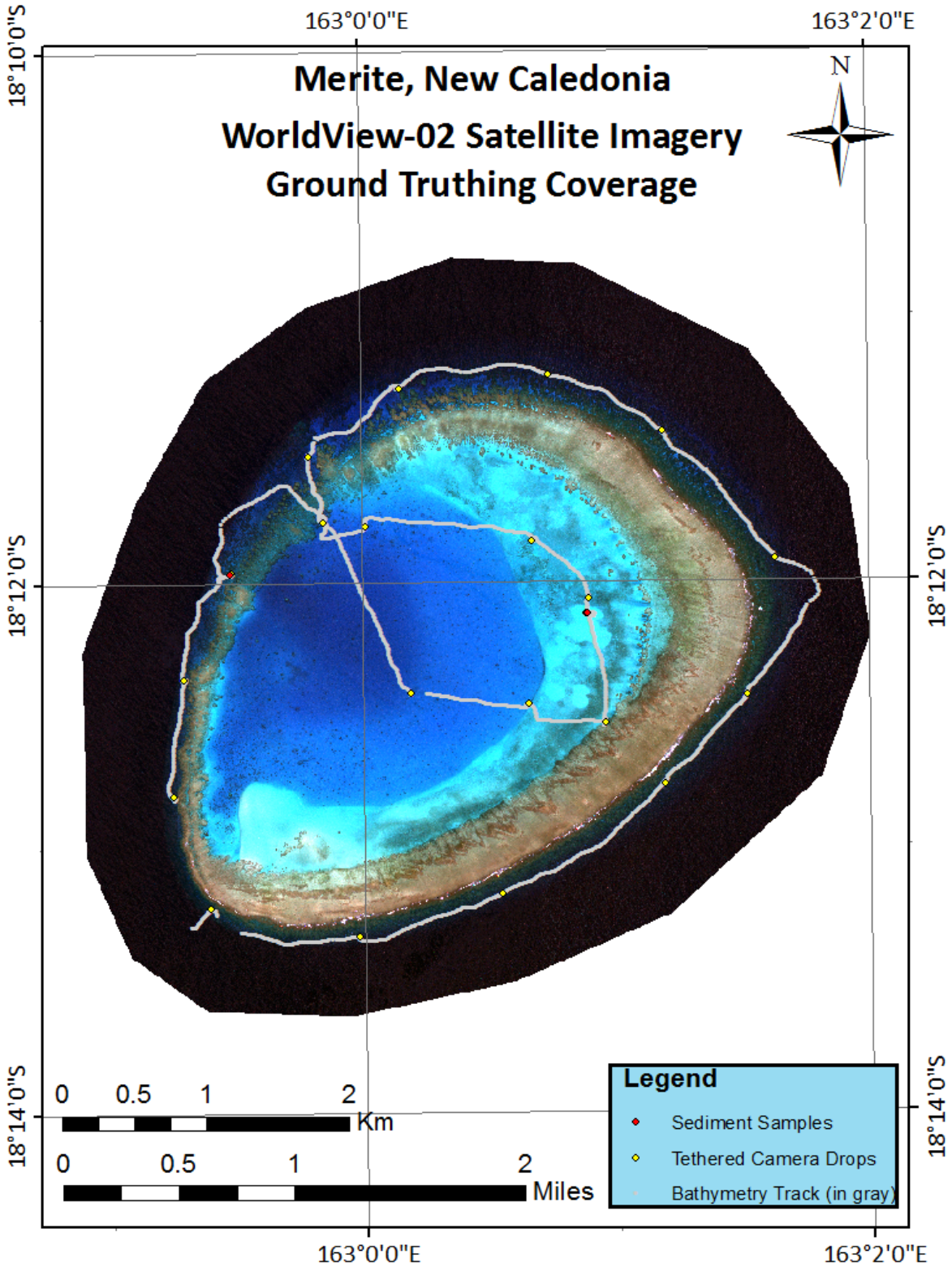

Fig. 12. Groundtruthing track and drop camera deployments around Merite.

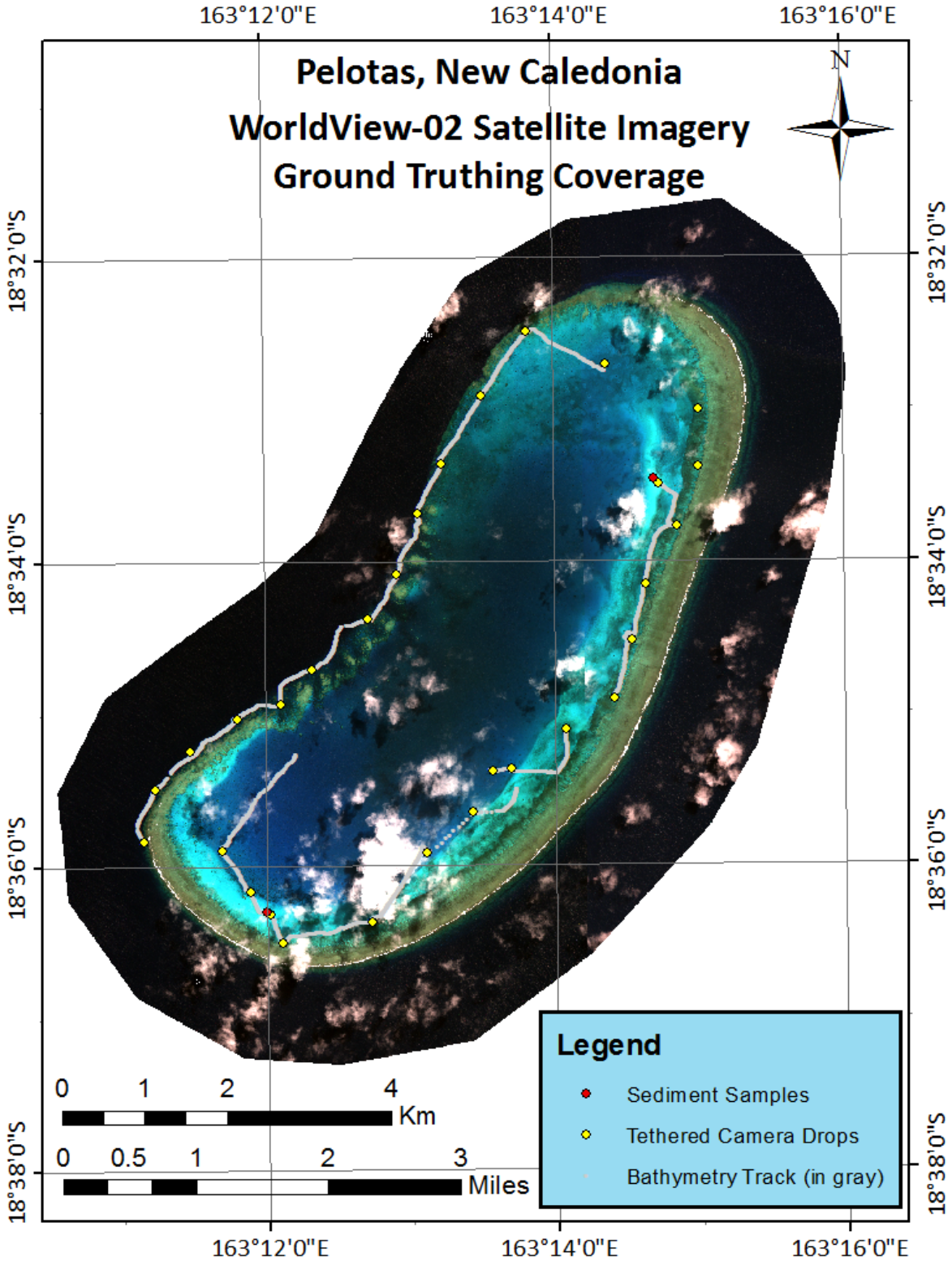

Fig. 13. Groundtruthing track and drop camera deployments around Pelotas.

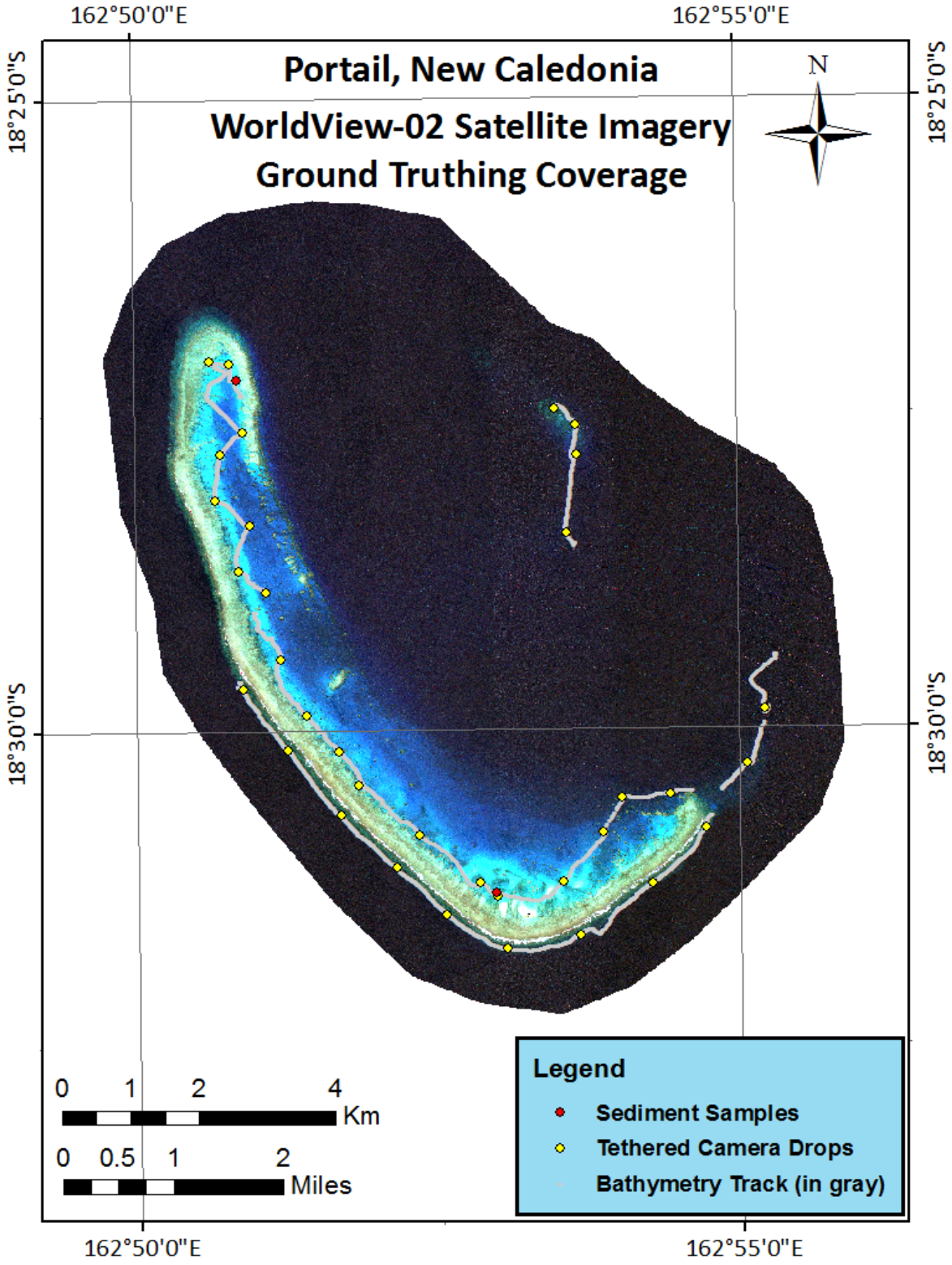

Fig. 14. Groundtruthing track and drop camera deployments around Portail.

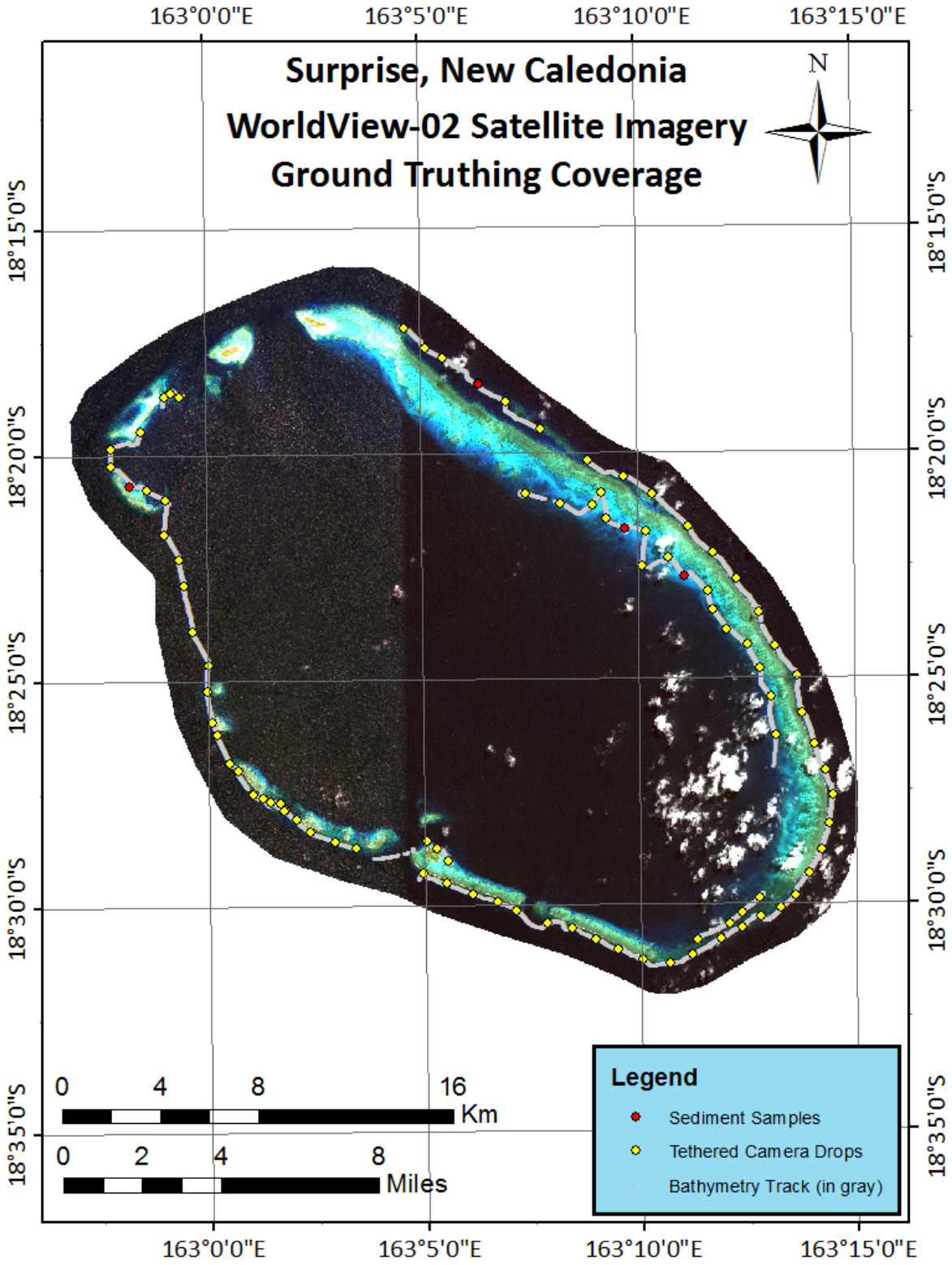

Fig. 15. Groundtruthing track and drop camera deployments around Surprise.

2. General Approach of SCUBA assessments:

Fish Assessments

For fish, abundance and size structure was collected for over 200 species of fishes (Appendix 1), targeting species that have a major functional role on reefs or are major fisheries targets. Reef fishes were assessed along 4 m X 30 m belt transects. Fish are recorded to the nearest cm. A T square marked in 5 cm increments was used to gauge fish size. A minimum of 6 transects were conducted by each "fish" diver per site. A roving survey was also completed to assess the total diversity and relative abundance (rare, common, and abundant) of reef fishes at each site.

Benthic cover

Cover of major functional groups (corals identified to genus, sponges, other invertebrates, and six groups of algae including macroalgae, crustose coralline algae, erect coralline algae, fine turfs, turf algae with sediment and cyanobacteria) and substrate type (hardground, sand, mud, rubble, recently dead coral, bleached coral, live coral) were assessed along 10 m transects using recorded observations and/or photographic assessments. Recorded observations involved a point intercept method, whereas the organism and substrate was identified every 10 cm along a 10 m transect (total 100 points/transect), with a minimum of six transects examined per location. When possible, surveys were completed at 30, 25, 20, 15, 10 and 5 m depth.

Photographic assessment

A 10 m long transect tape was extended along depth contours at 30, 20, 15, 10 and 5 m depth. Continuous digital still photographs were taken of the reef substrate from a height of approximately 0.6-0.75 meters above the substrate, using a one meter bar divided into 5 cm increments placed perpendicular to the transect tape as a scale bar. Approximately 20 photographs were taken per transect to allow for overlap between adjacent images with two photo transects (each 10 m in length) per depth. Images were downloaded onto a computer, and benthic community composition, coral cover and cover of other organisms and substrate type, and to determine the size (planar surface area) of corals were analyzed using Coral Point Count (CPCE) software developed by the National Coral Reef Institute (NCRI). Cover was determined by recording the benthic attribute located directly below random points (30-50 points per photograph). Planar surface area was measured by tracing the outline of individual corals.

Coral assessments

A combination of quantitative methods including: belt transects, point intercept transects, radial plots and quadrats were used to assess corals, fish and other benthic organisms. Five measures were recorded for corals: 1) benthic cover (point intercept, see above); 2) coral diversity and abundance (by genus, except certain common species); 3) coral size class distributions; 4) recruitment; and 5) coral condition. Additional information was collected on causes of recent mortality, including signs of coral disease and predation. Assessment of corals smaller than 4 cm was achieved by using a minimum of five 0.25 m^2 quadrats per transect, with each quadrat located at fixed, predetermined intervals (e.g. 2, 4, 6, 8, 10 m), alternating between the right and left side of the transect line. Recruits were identified in both point intercept surveys and belt

transects. Recruits were divided into two categories: corals up to 2 cm diameter and larger corals, 2-3.9 cm diameter.

Coral population structure and condition was assessed within belt transects (each 10 m x1), with a minimum of two transects completed per depth. Each coral, 4 cm or larger was identified (to genus at minimum) and its growth form was recorded. Visual estimates of tissue loss were recorded for each colony over 4 cm in diameter using a 1 m bar marked in 1 cm increments for scale. If the coral exhibited tissue loss, estimates of the amount of remaining tissue, percent that recently died and percent that died long ago were made based on the entire colony surface. Tissue loss was categorized as recent mortality (occurring within the last 1-5 days), transitional mortality (filamentous green algae and diatom colonization, 6-30 days) and old mortality (>30 days).

For each coral with partial or whole colony mortality, the cause of mortality is identified if possible. The diagnosis included an assessment of the type of disease, extent of bleaching, predation, competition, overgrowth or other cause of mortality. Each coral was first carefully examined to identify cryptic predators. Lesions were initially diagnosed into four categories: recent tissue loss, skeletal damage, color change, and unusual growth patterns; an individual colony could have multiple characteristics (e.g. color change and recent tissue loss). The location (apical, basal, and medial) and pattern of tissue loss (linear, annular, focal, multifocal, and coalescing) was recorded and when possible a field name was assigned. If an outbreak of coral disease was documented, sampling of the affected corals was undertaken to further characterize the disease (see below).

Motile invertebrates

Large motile invertebrates (urchins, octopus, lobster, large crabs, large gastropods, sea cucumbers) were identified and counted along coral belt transects and benthic point intercept surveys. In addition, one or two divers conducted timed swims at different depths to document the species diversity and abundance of sea cucumbers at each site assessed. This assessment included a documentation of the type of habitat occupied by these organisms.

Number of Islands	Number of dives	Benthic transects	Fish transects	Coral transects	Corals	Phototransects
10	76	432	432	216	24,000	176

Table 3. Summary of the coral reef assessments. The total number of benthic, fish and coral transects and number of corals assessed in five islands are shown.

Table 4. Locations of SCUBA assessments.

Date	Location	Long	Lat	SiteID	reef_zone	reef_type	exposure
10/28/2013	Ile des Pins	167.351200	-22.665100	NCPI01	lagoonal	emergent patch reef	leeward
10/28/2013	Ile des Pins	167.352500	-22.652200	NCPI02	lagoonal	emergent patch reef	leeward
10/28/2013	Ile des Pins	167.369600	-22.647600	NCPI03	lagoonal	submerged patch reef	leeward
10/29/2013	Ile des Pins	167.370900	-22.496300	NCPI04	fore reef	barrier	windward
10/29/2013	Ile des Pins	167.413500	-22.514700	NCPI05	fore reef	fringing	leeward
10/29/2013	Ile des Pins	167.301300	-22.576300	NCPI06	lagoonal	barrier	leeward
10/30/2013	Ile des Pins	167.564100	-22.639700	NCPI07	fore reef	fringing	windward
10/30/2013	Ile des Pins	167.549200	-22.599400	NCPI08	fore reef	barrier	windward
10/30/2013	Ile des Pins	167.449000	-22.717800	NCPI09	fore reef	seaward of barrier	windward
10/31/2013	Ile des Pins	167.196100	-22.569400	NCNE10	fore reef	emergent patch reef	windward
10/31/2013	Ile des Pins	167.207900	-22.559400	NCNE11	fore reef	emergent patch reef	leeward
10/31/2013	Ile des Pins	167.436000	-22.655400	NCPI12	lagoonal	fringing	leeward
10/31/2013	Ile des Pins	167.309000	-22.581200	NCPI13	lagoonal	fringing	leeward
11/1/2013	Ile des Pins	167.587200	-22.719300	NCPI14	fore reef	barrier	windward
11/1/2013	Ile des Pins	167.374000	-22.700600	NCPI15	fore reef	barrier	leeward
11/1/2013	Ile des Pins	167.542200	-22.740500	NCPI16	lagoonal	barrier	leeward
11/2/2013	Ile des Pins	167.300600	-22.458800	NCPI17	fore reef	barrier	windward
11/2/2013	Ile des Pins	167.236400	-22.486400	NCPI18	fore reef	barrier	windward
11/2/2013	Ile des Pins	167.306500	-22.639800	NCPI19	lagoonal	submerged reef platform	leeward
11/3/2013	Ile des Pins	167.533000	-22.554300	NCPI20	fore reef	barrier	windward
11/3/2013	Ile des Pins	167.442300	-22.514400	NCPI21	lagoonal	patch reefs	leeward
11/4/2013	Prony Bay	166.843980	-22.313930	NCPR22	bay	fringing reef	leeward
11/4/2013	Prony Bay	166.890470	-22.365910	NCPR23	bay	fringing reef	leeward
11/4/2013	Prony Bay	166.850950	-22.351960	NCPR24	bay	fringing reef	leeward
11/6/2013	Pelotas	163.235280	-18.597630	NCPE25	fore reef	atoll	windward
11/6/2013	Pelotas	163.211880	-18.570950	NCPE26	fore reef	atoll	leeward
11/7/2013	Cook Reef	163.572560	-18.948290	NCCR27	fore reef	barrier	windward
11/7/2013	Cook Reef	163.551390	-18.870860	NCCR28	fore reef	barrier	windward
11/7/2013	Cook Reef	163.484680	-18.835930	NCCR29	fore reef	barrier	leeward
11/8/2013	Cook Reef	163.559310	-19.098620	NCCR30	fore reef	barrier	leeward
11/8/2013	Cook Reef	163.505490	-18.985730	NCCR31	backreef	barrier	windward
11/8/2013	Cook Reef	163.414470	-18.884540	NCCR32	fore reef	barrier	leeward
11/9/2013	Cook Reef	163.682480	-19.052900	NCCR33	fore reef	barrier	windward
11/9/2013	Cook Reef	163.630420	-19.060560	NCCR34	channel	barrier	leeward
11/9/2013	Cook Reef	163.439820	-18.877390	NCCR35	backreef	barrier	leeward
11/10/2013	Cook Reef	163.530500	-18.849290	NCCR36	fore reef	barrier	windward
11/10/2013	Cook Reef	163.447740	-18.852290	NCCR37	backreef	barrier	leeward
11/10/2013	Cook Reef	163.434650	-18.853860	NCCR38	fore reef	barrier	leeward

Date	Location	Long	Lat	SiteID	reef_zone	reef_type	exposure
11/11/2013	Portail	162.908370	-18.508120	NCPO39	backreef	atoll	windward
11/11/2013	Portail	162.888930	-18.458190	NCPO40	backreef	atoll	windward
11/11/2013	Portail	162.837600	-18.462720	NCPO41	fore reef	atoll	leeward
11/12/2013	Huon	163.8723381	-20.2633042	NCPU42	fore reef	barrier	leeward
11/13/2013	Huon	162.897520	-17.887250	NCHU43	fore reef	atoll	windward
11/13/2013	Huon	162.892090	-17.936250	NCHU44	fore reef	atoll	leeward
11/13/2013	Huon	162.906310	-17.997750	NCHU45	lagoonal	atoll	leeward
11/14/2013	Huon	162.828220	-18.061290	NCHU46	fore reef	atoll	leeward
11/14/2013	Huon	162.896030	-17.978180	NCHU47	fore reef	atoll	leeward
11/14/2013	Huon	162.916210	-18.035980	NCHU48	lagoonal	atoll	leeward
11/15/2013	Huon	162.888350	-18.232600	NCHU49	fore reef	atoll	windward
11/15/2013	Huon	162.841220	-18.195550	NCHU50	fore reef	atoll	leeward
11/15/2013	Huon	162.815930	-18.132540	NCHU51	channel	atoll	leeward
11/16/2013	Huon	162.922450	-17.919760	NCHU52	fore reef	atoll	windward
11/16/2013	Huon	162.892180	-17.951410	NCHU53	fore reef	atoll	leeward
11/16/2013	Huon	162.932280	-17.969120	NCHU54	fore reef	atoll	windward
11/17/2013	Guilbert	163.109680	-17.999010	NCGU55	fore reef	atoll	leeward
11/17/2013	Guilbert	163.129090	-18.014810	NCGU56	fore reef	atoll	windward
11/17/2013	Huon	162.917110	-17.969490	NCHU57	back reef	atoll	leeward
11/18/2013	Guilbert	163.088900	-18.017410	NCGU58	fore reef	atoll	leeward
11/18/2013	Guilbert	163.075200	-18.057830	NCGU59	fore reef	atoll	windward
11/18/2013	Huon	162.965560	-18.020240	NCHU60	fore reef	atoll	windward
11/18/2013	Surprise	163.127685	-18.506303	NCSU61	fore reef	atoll	leeward
11/18/2013	Surprise	163.227386	-18.496701	NCSU62	fore reef	atoll	windward
11/18/2013	Surprise	163.231435	-18.429836	NCSU63	fore reef	atoll	windward
11/19/2013	Merite	163.028170	-18.200190	NCME64	fore reef	atoll	windward
11/20/2013	Merite	163.017210	-18.214630	NCME65	fore reef	atoll	windward
11/20/2013	Surprise	163.024580	-18.464710	NCSU66	fore reef	atoll	leeward
11/21/2013	Surprise	163.119710	-18.312820	NCSU67	fore reef	atoll	windward
11/21/2013	Surprise	163.040020	-18.278390	NCSU68	fore reef	atoll	windward
11/22/2013	Surprise	162.987440	-18.299690	NCSU69	channel	atoll	leeward
11/22/2013	Surprise	162.991180	-18.395940	NCSU70	channel	atoll	leeward
11/22/2013	Surprise	163.100360	-18.497180	NCSU71	fore reef	atoll	leeward
11/23/2013	Portail	162.842010	-18.476420	NCPO72	fore reef	atoll	leeward
11/23/2013	Portail	162.870390	-18.519350	NCPO73	fore reef	atoll	leeward
11/23/2013	Surprise	163.079880	-18.463230	NCSU74	lagoonal	atoll patch reef	leeward
11/24/2013	Pelotas	163.252750	-18.538990	NCPE75	fore reef	atoll	windward
11/24/2013	Pelotas	163.186900	-18.601360	NCPE76	fore reef	atoll	leeward

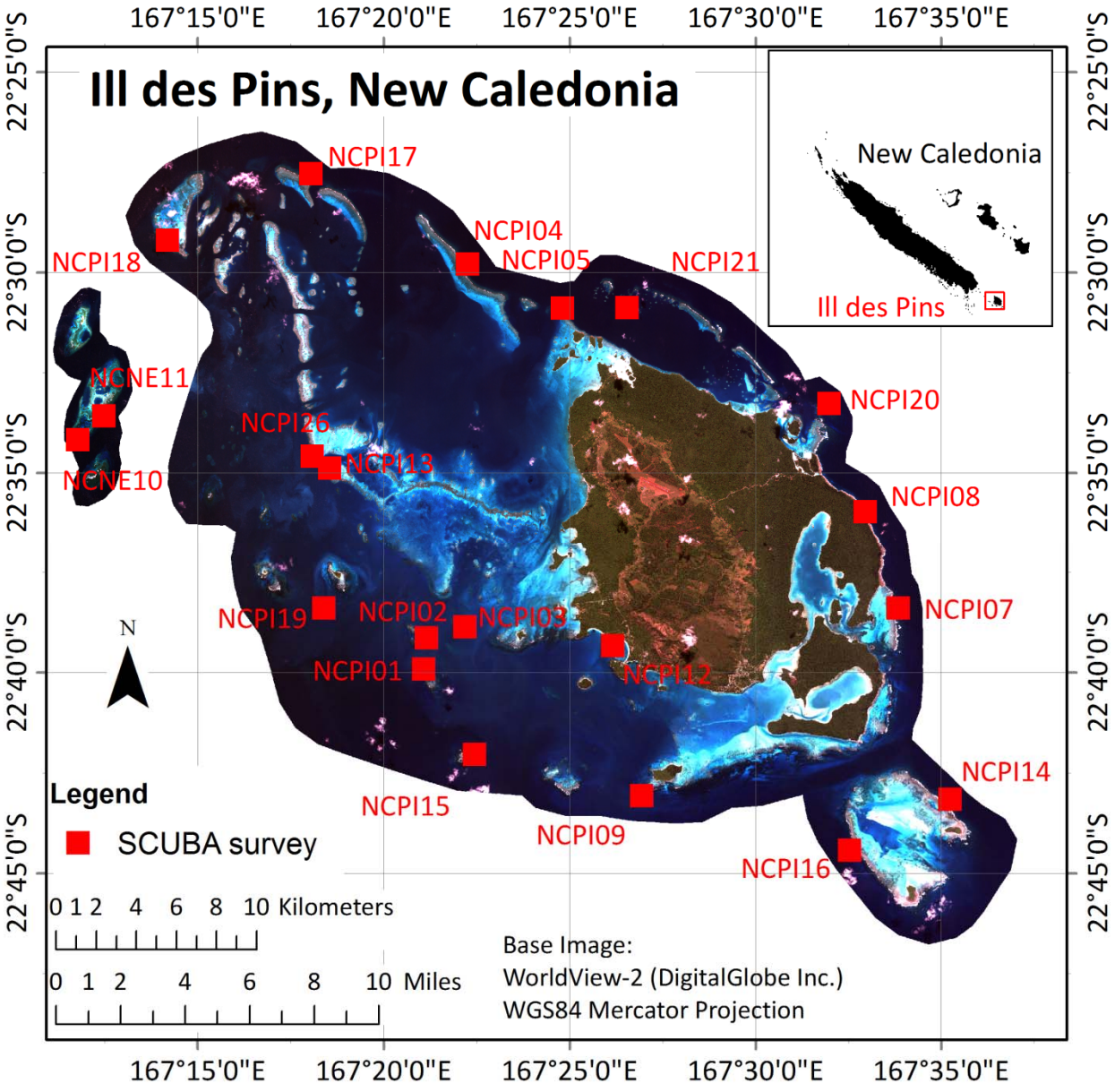

Fig. 16. Location of sites assessed using SCUBA around Ile des Pins and Neulka.

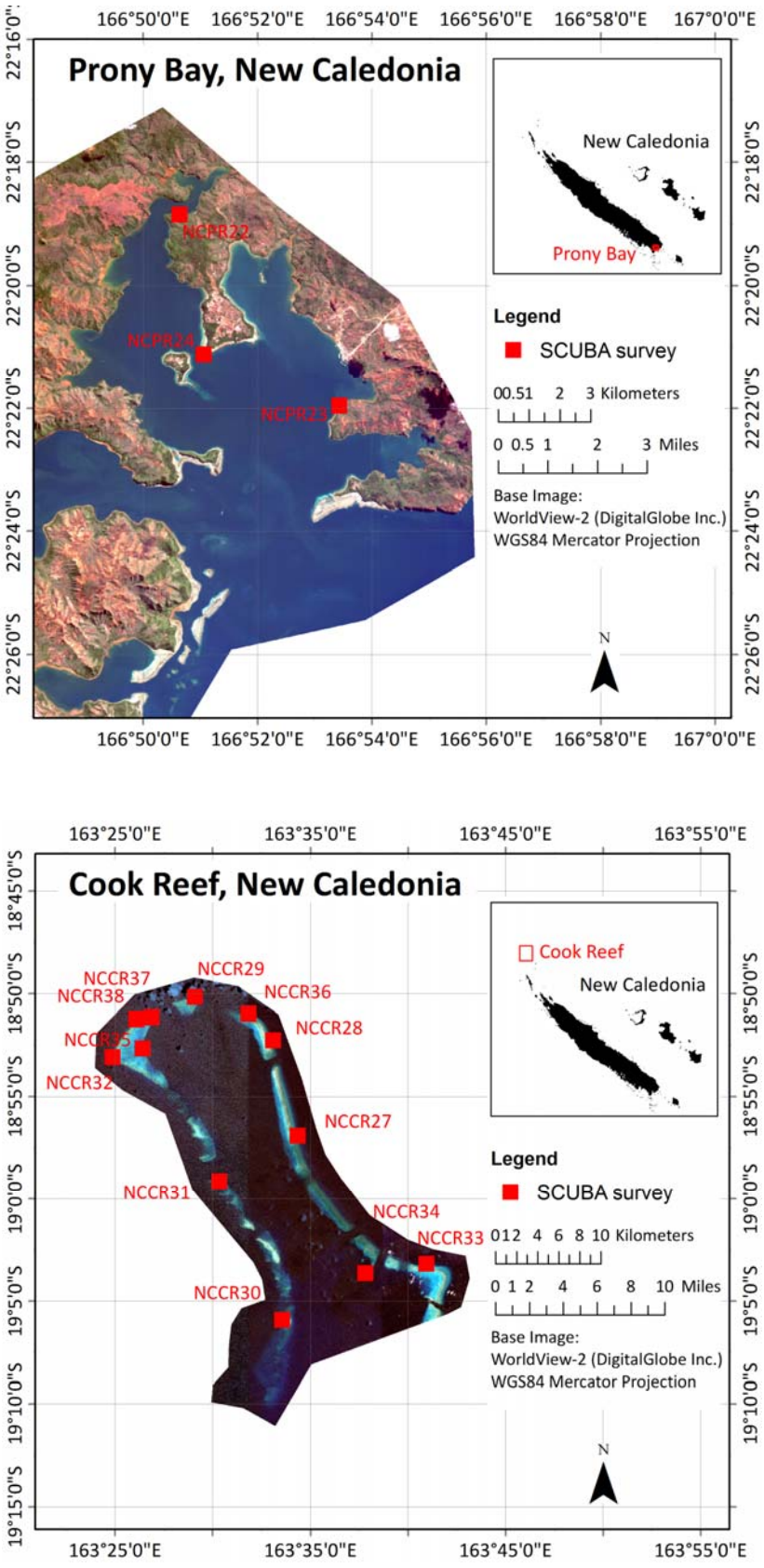

Fig. 17. Location of SCUBA assessments around Prony Bay and Cook Reef.

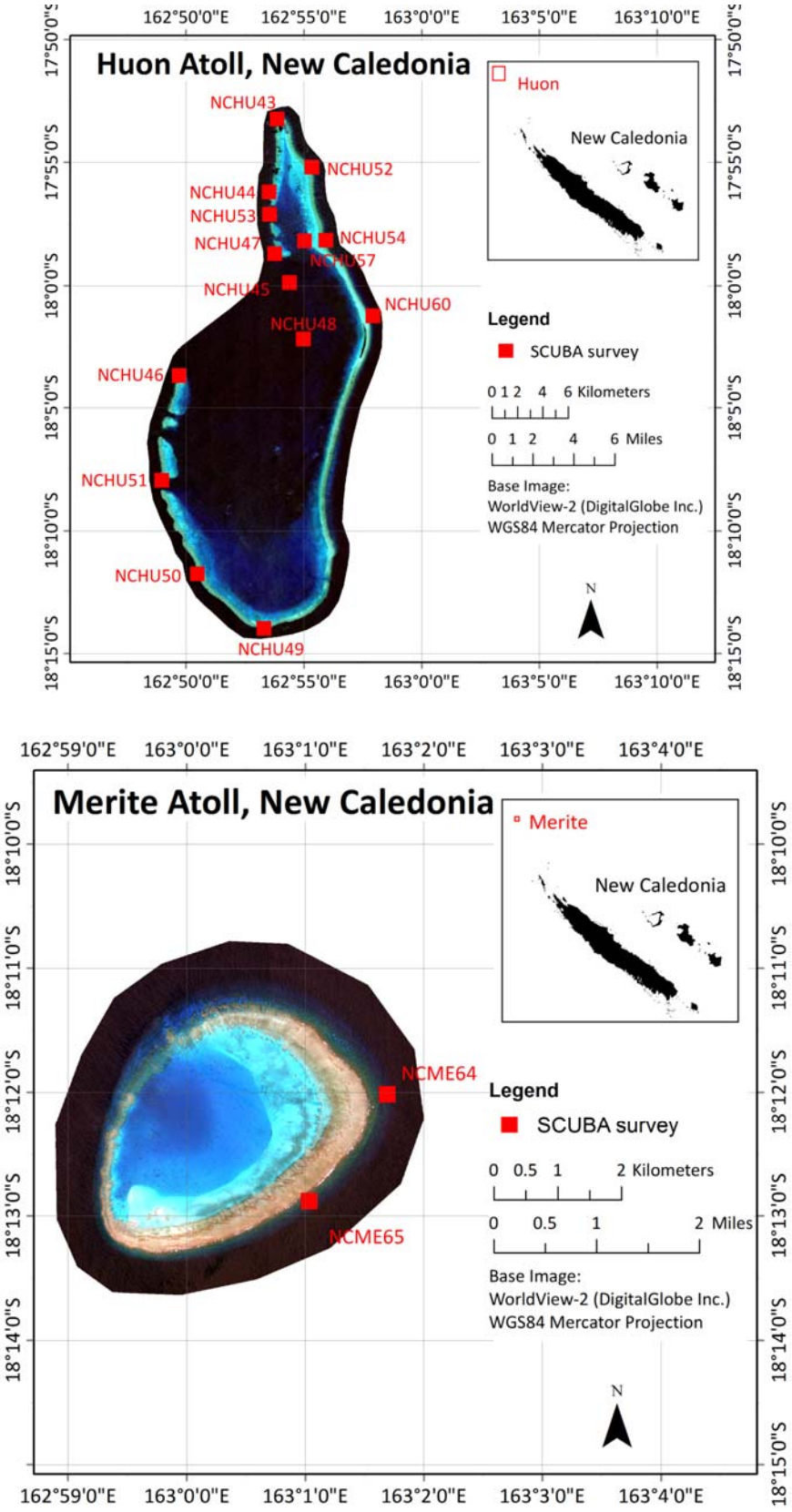

Fig. 18. Location of SCUBA assessments around Huon (top) and Merite (bottom).

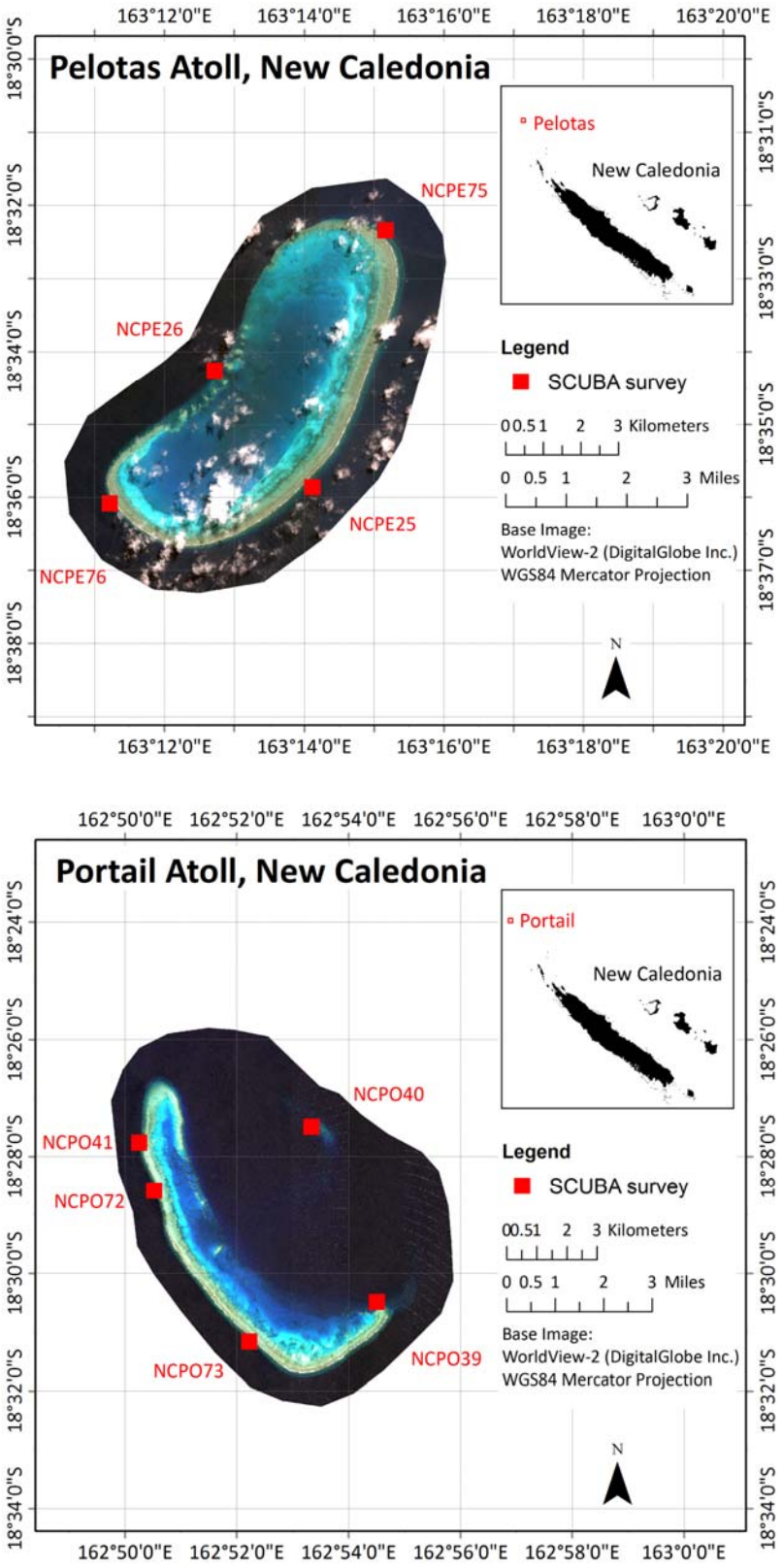

Fig. 19. Location of SCUBA assessments around Pelotas (top) and Portail (bottom).

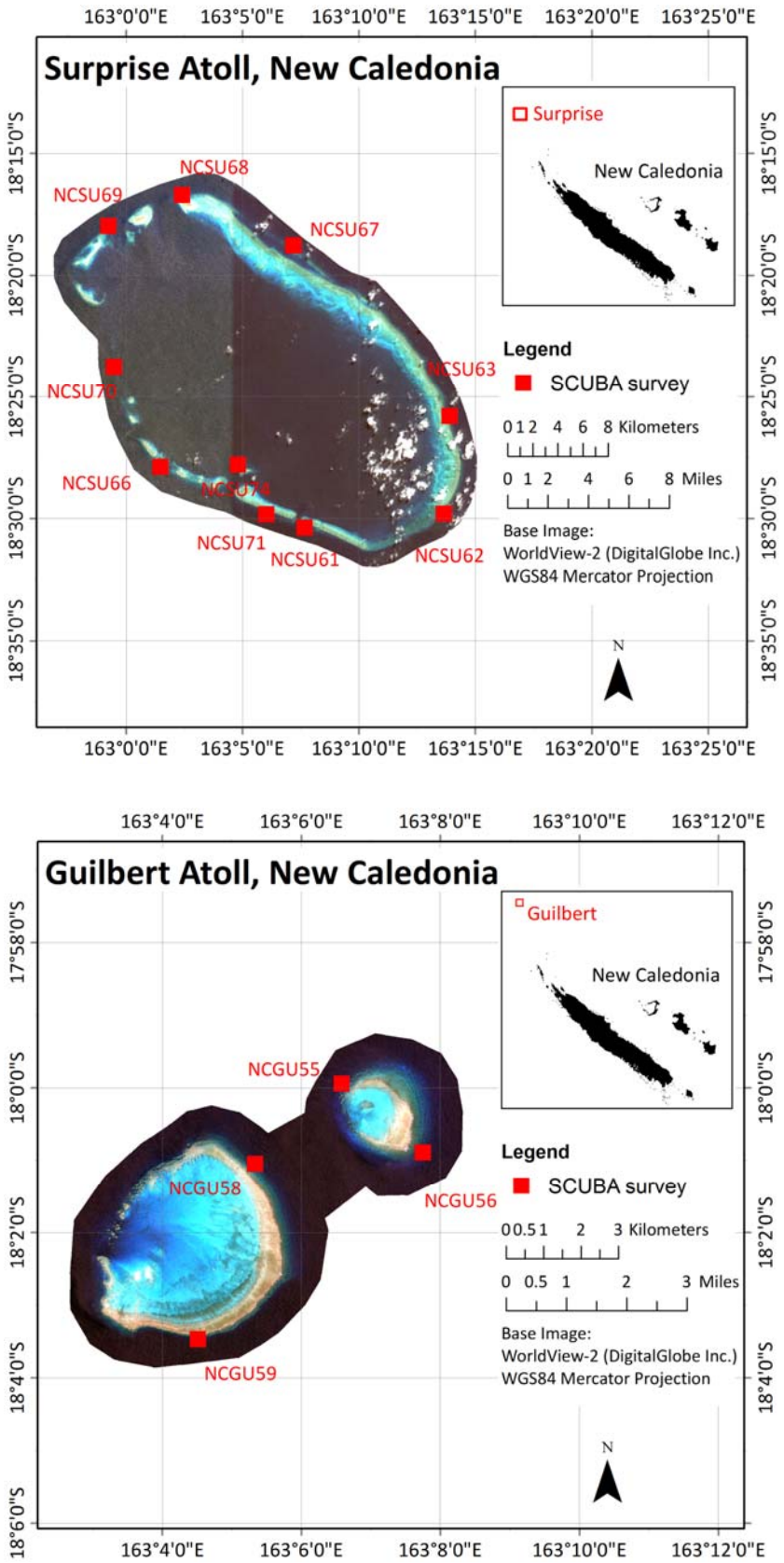

Fig. 20. Location of SCUBA assessments around Surprise (top) and Guilbert (bottom).

3. Coral reef research

Sediment collection:

Sediment samples were collected using two different methods. The first method used SCUBA and concentrates on the sloped outer flanks of the reef, whilst the second employs a grab sampler to investigate the sediment composition inside the reef lagoon. At each sample station, approximately 100 ml of sediment was shoveled by hand into a 125 ml plastic bottle. Stations were selected so that no benthic life is disturbed or injured. Digital pictures of underwater landscapes surrounding the sampling site were also gathered to provide a visual record of the station. Up to ten samples were collected per day.

In the lagoons, sediment was collected using a Petite Ponar® Grabber. The grabber was attached to an electronic winch wound with 50m of braided polyester line. The grabber was slowly deployed over the side of the boat until it settles on the seafloor, causing the winch line to slacken and the grab to shut. Once the grab is retrieved, it was lifted into the boat and the sediment collected. For each deployment, 100 ml of sediment was shoveled by hand into a 125 ml plastic bottle. A maximum of five samples were taken per day.

In the laboratory, the samples were rinsed with a weak bleach solution (30% bleach and 70% tap water) and allowed to set for several days. This process halts biological activity and preserves the sediments. The samples were dried in an oven at low heat (50°-70°c) for 24 hours, and then analyzed using a Camsizer® instrument to determine the size and shape of sediment grains. The data are being used to create sediment maps akin to the benthic habitat maps.

Island	Number of samples
Huon	23
Guilbert	6
Merite	6
Portail	8
Pelotas	4
Surprise	12
Neulka	5
Pins	22
Cook reef	13
Total	**99**

Table 5. Total number of sediment samples.

Coral symbiont analysis:

This component involved two aspects: 1) sampling colonies of *Pocillopora* from different habitats, depths and locations to characterize their symbionts; and 2) diurnal and nocturnal measurements of the fluorescence of these corals using a PAM fluorometer. In each location the diver started at 30 m and progressively works up to 5 m depth, sampling a minimum of three Pocilloporid corals per depth gradient (5, 10, 15, 20, 25, and 30). Only pocilloporid corals located under randomly generated coordinates from each depth was sampled, with three

representative samples taken from each colony. Corals were separated each by a minimum of 5 m in attempt to avoid sampling ramets of the same genet. For each sampled coral, clippers were used to break off a small fragment of coral tissue (three to four polyps). A photograph was taken of each colony prior to sampling, and colony size was measured in three dimensions (maximum length, width, and height to the nearest 10 cm). A maximum of 30 colonies were collected per species on each reef. Fragments were placed in individual zip-lock bags underwater and then transferred to vials containing DMSO on shore and stored in a -20°C freezer. Typical biopsies were <0.5cm^2 in total surface area. In a subsample of the colonies that were sampled (10 colonies per reef or island, all at 10 m depth), triplicate measurements of fluorescence were taken during the day and again at night using a PAM fluoremeter.

Table 6. Total number of samples of *Pocillopor*a collected from each reef, island or atoll.

Location	*P. damicornis*	*P. eydouxi*	*P. verrucosa*	*Pocillopora* sp.	Total
Cook Reef	29	10	42		81
Guilbert		20	16	4	40
Huon	28	4	29		61
Neulka	14	4	11		29
Prony Bay	16				16
Pelotas	6	5	12		23
Ile des Pins	59	11	20		90
Merite	1	4	20		25
Portail	13	9	22	1	45
Surprise	10	13	28	4	55
Total	**176**	**80**	**200**	**9**	465

Fig. 21. Sampling a *Pocillopora eydouxi* colony.

Ocean acidification:

This research involved two components, characterizing water chemistry and collecting coral samples to correlate water chemistry to coral growth rates. Water chemistry analysis involved three aspects: 1. Three to four seawater bottle samples (500 ml) were collected from each site visited. Seawater samples were preserved with 2 µl of saturated HgCl2 and sealed with large rubber bands to prevent any changes to the carbonate system before analysis. Total CO_2 (TCO_2) is being measured coulometrically and total alkalinity (TA) measured utilizing a gran titration by Dr. Derek Manzello (NOAA/AOML) in our laboratory in Miami, Florida (USA). 2. An autonomous pH sensor was deployed on the bottom for the duration of our visit to each site. This instrument measured the diel variability in seawater CO_2, to complement the bottle samples obtained. 3. At each dive location, we sampled the water for the duration of a dive to obtain instantaneous measures of TCO_2, TA and temperature. These parameters allowed calculation of the carbonate system of seawater (i.e., partial pressure of CO2 (pCO_2), pH and Ω).

During each dive, one diver collected small coral cores from massive coral species (*Porites lobata, Goniastrea, Pavona clavus, Favia stelligera, Cyphastrea serailia, Platygyra, Montipora, Diploastrea*) using a pneumatic drill, to examine long-term patterns in coral growth rates. Up to ten cores were per location (species will depend on local abundance of retrievable cores). These cores are small, approximately 3 cm in diameter and 7 cm in maximum length. All core holes were filled with cement plugs and epoxy to aid tissue recovery of the parent colony. Samples were carried back to Miami and are being assessed using a micro-CT machine to determine linear extension, bulk-density, and calcification.

Table 7. Number and location of coral cores taken for growth measurements.

Island	Species	Number	Size	Fixation
Cook	*Porites lobata*	20	~3cm diam. X 9 cm length	Dry
Cook	*Pavona clavus*	1	~3cm diam. X 9 cm length	Dry
Guibert	*Astreopora* sp	1	~3cm diam. X 9 cm length	Dry
Guibert	*Porites lobata*	18	~3cm diam. X 9 cm length	Dry
Huon	*Astreopora* sp	4	~3cm diam. X 9 cm length	Dry
Huon	*Porites lobata*	44	~3cm diam. X 9 cm length	Dry
Huon	*Porites lobata*	4	~5cm diam. X 30 cm length	Dry
Pelotas	*Astreopora* sp	1	~3cm diam. X 9 cm length	Dry
Pelotas	*Porites lobata*	16	~3cm diam. X 9 cm length	Dry
Pins	*Porites lobata*	54	~3cm diam. X 9 cm length	Dry
Portail	*Porites lobata*	22	~3cm diam. X 9 cm length	Dry
Prony Bay	*Porites lobata*	14	~3cm diam. X 9 cm length	Dry
Surprise	*Astreopora* sp	1	~3cm diam. X 9 cm length	Dry
Surprise	*Porites lobata*	32	~3cm diam. X 9 cm length	Dry
Surprise	*Porites lobata*	1	~5cm diam. X 30 cm length	Dry
Total		223		

Coral Health

This research seeks to understand if it is possible to detect sub-lethal levels of stress in corals using molecular biomarkers. Currently, the only way to know if the corals are stressed is if they show signs of stress (e.g. partial colony mortality) which usually occurs after the environmental conditions have already changed. By using expression levels of certain genes, proteins, and metabolites, an index of health will be developed that can be used to forecast the future condition of a reef and identify a potential environmental perturbation before it manifests through coral mortality. One of the dominant reef building coral genera found throughout the Indo-Pacific, *Pocillopora*, is the model animal that was sampled. Total number of samples collected are shown in Table 8.

Table 8. Samples of *Pocillopora damicornis* collected to assess health.

Location	weight (grams)	No. samples
Pins	10	76
Neulka	0.8	7
Prony Bay	0.7	7
Pelotas	0.3	3
Cook Reef	1.9	19
Portail	0.4	4
Huon	0.9	9
Surprise	1.9	19
Total	16.9	144

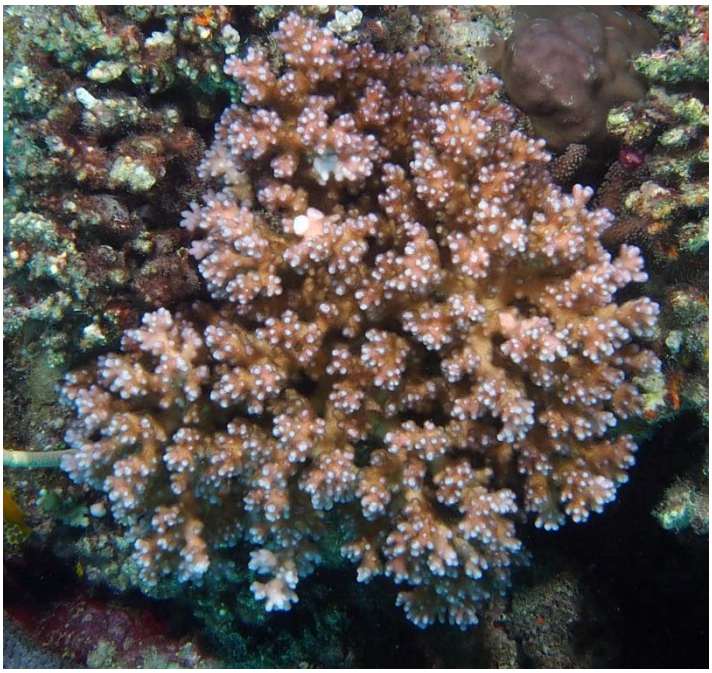

Fig. 22. *Pocillopora damicornis* (cauliflower coral).

Coral Disease

Coral assessments included recorded observations of the taxa, abundance, size structure and condition within belt transects. For each measured coral, the colony was carefully scanned to identify conditions affecting its health, including signs of overgrowth, predation and disease. In general, very few colonies with coral diseases were observed. The only exception was on some of the northern atolls, where numerous colonies of table *Acropora* were affected by white syndrome and yellow band disease.

A total of 24 samples of white syndrome were collected from table acroporids and staghorn acroporids on two reefs off Surprise Atoll. Three samples of yellow band disease were collected from table acroporids on the same reefs.

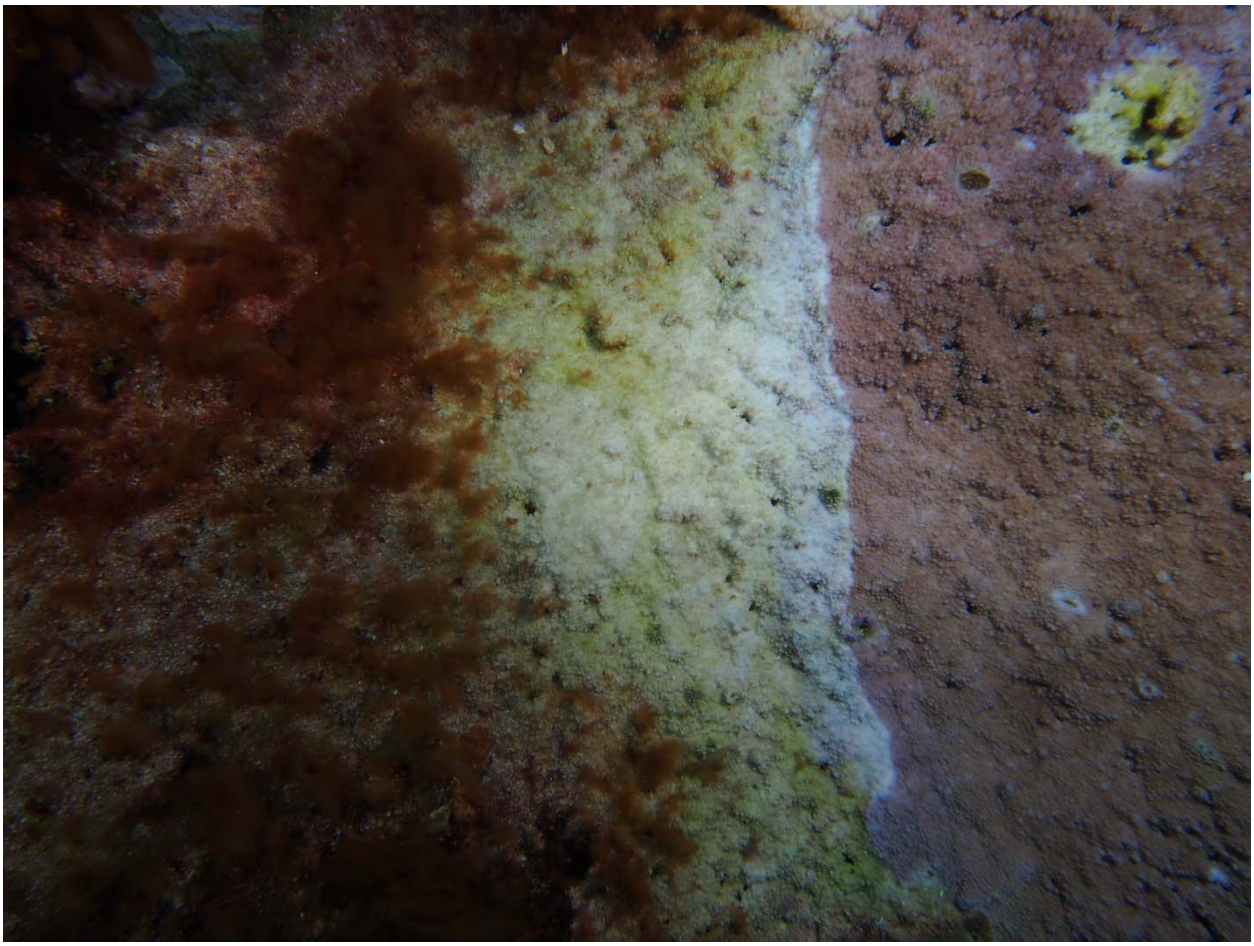

Fig. 23. Colony of a table *Acropora* with white syndrome. Areas of exposed skeleton grades from a thin white band adjacent to living tissue, to an area with diatoms and fine filamentous algae, and an area of older mortality with CCA and cyanobacteria.

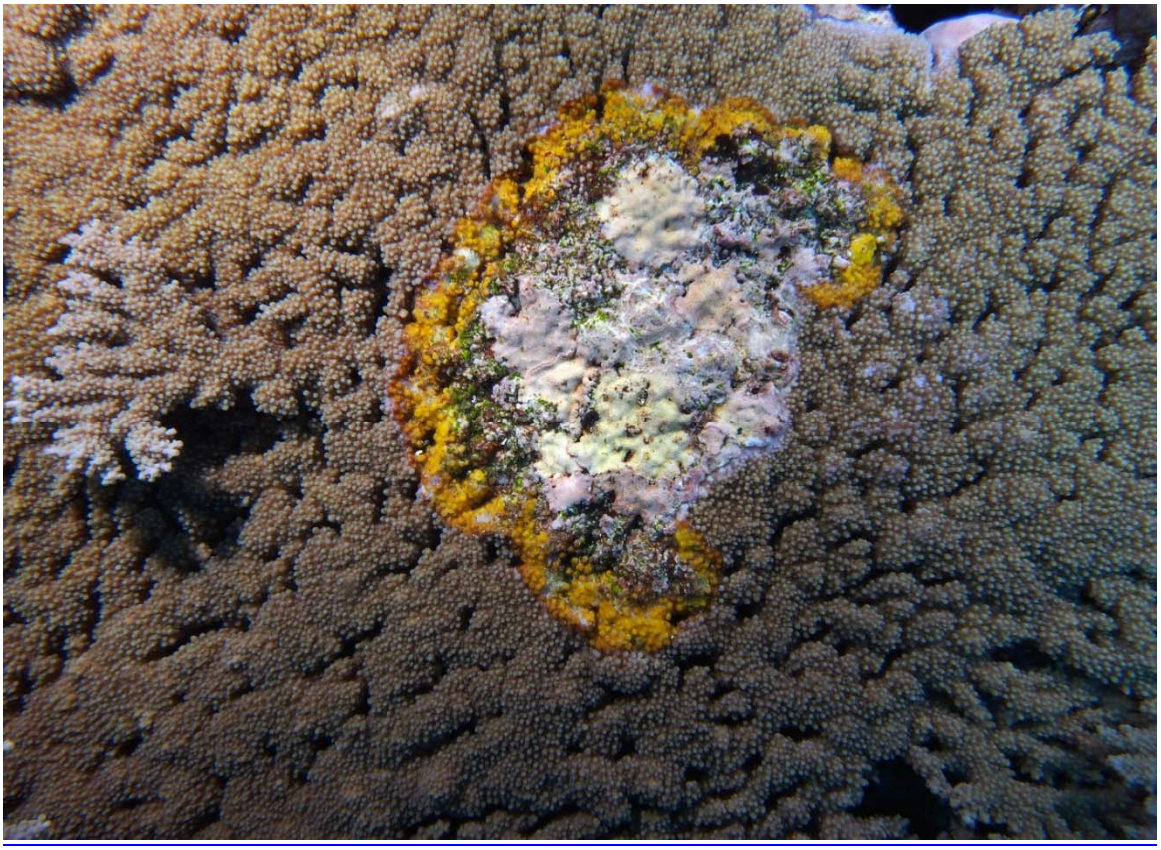

Fig. 24. A table acroporid with yellow band disease. The old dead area is colonized by crustose coralline algae.

Giant clams (I.R.D.)

A total of 566 biopsies were taken of giant clam tissue for DNA extraction and further population genetic and phylogeography analysis. This included 130 from Ile des Pins and Prony,59 from Cook Reef and 377 from the northern atolls. The samples were from *Tridacna maxima* and *Hippopus hippopus*, with reference samples taken from *T. derasa* and *T. squamosa.*

Fig. 25. *Tridacna maxima* giant clam.

Algae of Ile des Pins (I.R.D.)

A total of 335 specimens of algae were collected and pressed onto herbarium paper for a reference collection. Samples of these algae were preserved in formalin for histology and in ethanol and silica gel for DNA analysis. The samples included 1) gelatinous red algae of the following genera: *Dudresnaya, Gibsmithia, Peleophycus, Trichogloea, Kallymenia, Halymenia, Platoma, Predaea*; 2) the genus *Melanthalia* which is endemic to the region of Nouvelle-Calédonie -Australie du sud et Nouvelle-Zélande; 3) green algae in the group *Bryopsidales (Codium, Halimeda, Rhipilia, Avrainvillea)* and *Caulerpa;* and 4) brown algae in the groups Dictyotales (*Padina, Stypopodium, Dictyota, Distromium*) and Sporochnales (*Sporochnus, Nereia*).

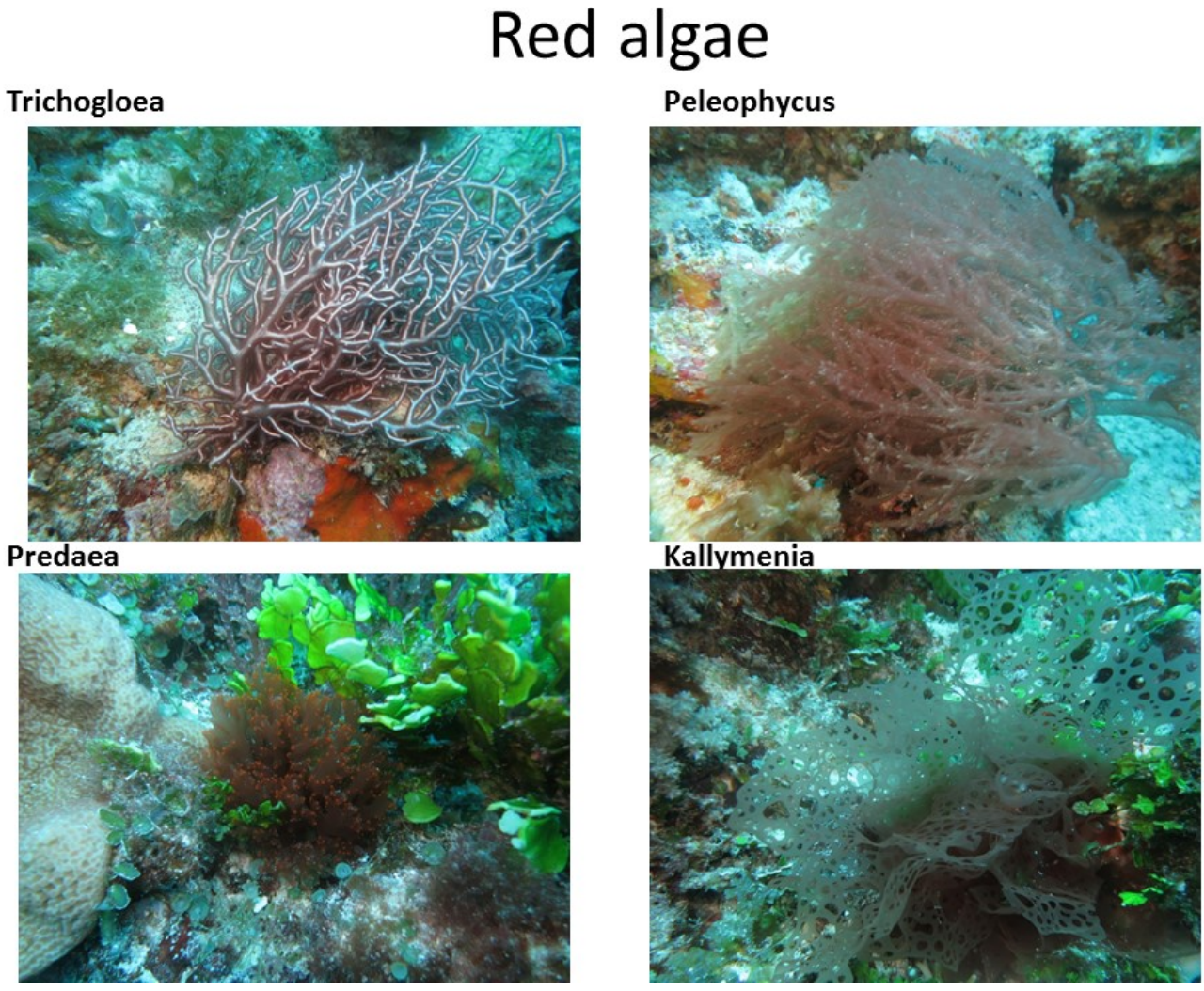

Fig. 26. Examples of red algae found at Ile des Pins.

Invertebrate biodiversity (I.R.D.)

A total of 664 different species of invertebrates were collected from shallow water in the four regions. These were photographed, genetic samples were taken for barcoding and specimens were preserved for a reference collection.

Table 9. Summary of invertebrate species collected in three regions.

Location	Mollusc	Echinoderm	Crustacean	Other
Ile des Pins + Prony Bay	48	73	138	1
Cook Reef	17	49	49	3
Northern atolls	48	84	154	10
Total	113	206	331	14

Extent of auto and heterotrophy in corals (I.R.D.)

60 coral nubbins belonging to three different coral species: Pocillopora damicornis, Acropora sp. and Porites digitata have been collected from the reefs of Ile des Pins. These samples have been frozen and then prepared to analyze carbon and nitrogen isotope ratios (δ13C and δ15N) in the zooxanthellae, host tissue, and whole symbiotic association

Fig. 27. A cuttlefish on a shallow lagoonal reef in Huon.

Appendix 1. List of Participants

Name	Institution	Function
Phil Renaud	Khaled bin Sultan Living Oceans Foundation (KSLOF)	Executive Director
Andy Bruckner	Khaled bin Sultan Living Oceans Foundation (KSLOF)	Chief Scientist
Allison Barrat	Khaled bin Sultan Living Oceans Foundation (KSLOF)	Communications
Gwilym Rowlands	Nova Southeastern University National Coral Reef Institute	GIS Analyst
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	Nova Southeastern University National Coral Reef Institute	Habitat mapping
Serge Andrefouet	Institut de Recherche pour le Développement, New Caledonia	IRD Lead Scientist
Cécile Fauvelot	Institut de Recherche pour le Développement, New Caledonia	IRD Chief Scientist
Antoine Gilbert	Project manager, GINGER-SOPRONER	Scientific diver
Alex Dempsey	Nova Southeastern University National Coral Reef Institute	Benthic surveyor
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	Phycologist
Fanny Houlbreque	Institut de Recherche pour le Développement, New Caledonia	Coral physiologist
Eghbert Elvan Ampou	Institut de Recherche pour le Développement, New Caledonia	Scientific diver
Daphné Grulois	Institut de Recherche pour le Développement, New Caledonia	Scientific diver
Robert Gardiner	Nova Southeastern University National Coral Reef Institute	Groundtruthing
Ernie Kovacs	Independent contractor	Cameraman
Dawn Bailey	Dive-In OCEAN foundation	Coral surveyor
Kate Fraser	Independent contractor	Fish surveyor
Nick Cautin	Dive Safety Officer	Diving operations