Field Report

GLOBAL REEF EXPEDITION: Great Barrier Reef, Australia

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Front cover: Giant grouper (*Epinephelus lanceolatus*) with juvenile golden trevally (*Gnathanodon speciosus*) swimming above a mound of *Pavona cactus* on a mid-shelf reef in the northern Great Barrier Reef Marine Park. Photo by Andrew Bruckner.

Back Cover: A large stand of staghorn coral, *Acropora* spp. on Wood Reef. Photo by Ken Marks.

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All images are by Andrew Bruckner unless noted otherwise. All maps were completed by Alexandra Dempsey.

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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*®.

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Executive Summary

The Khaled bin Sultan Living Oceans Foundation completed a detailed assessment of the status of coral reefs and coral reef species on the northern Great Barrier Reef, Australia between September 1, 2014 and October 2, 2014. Partners contributing to this project included scientists from Wildlife Marine, University of Queensland, James Cook University, Scripps Institution of Oceanography, University of the Philippines, National Museum of Marine Biology and Aquarium Taiwan, University of Hawaii-Manoa, Woods Hole Oceanographic Institute, University of Southern California at Santa Barbara, Atlantic and Gulf Reef Assessment program, and Flinders University. The main objective of the research was to evaluate the effects of different management regimes on reef fish, coral and benthic communities on selected reefs in the northern Great Barrier Reef. A total of 30 reefs between 11° and 15° south latitude were selected for evaluation. The experimental design included 10 triplicates, each represented by a reef in the Preservation (Pink) Zone, Marine National Park (Green) Zone and Habitat Protection (Blue) Zone, spread across inner, mid-shelf and outer shelf locations. On each of the 30 reefs, six sites were randomly selected; three were located on the windward and three on the leeward side, for a total of 180 sites. Surveys focused on 10 m depth, with additional data collected between 5-30 m when possible. At each site, replicate long-distance shark and pelagic fish surveys (400 m X 10 m transects), reef fish assessments (4 m X 30 m transects), coral assessments (1 m X 10 m belt transects), photographic transects (1 m X 10 m), benthic assessments (10 m point intercept surveys) and rugosity measures (10 m chain transects) were completed. Additional rapid assessments using the *Eye of the Reef* (5 m radius) circular swim method were undertaken to collect semi-quantitative data on cover, growth forms, abundance and condition of reef building corals and other resilience data.

Over the 30 days, surveys were completed at 166 sites on 29 of the 30 proposed reefs and 145 shark and pelagic fish surveys at 74 stations on these reefs. Scientists conducted a total of 565 reef fish surveys, 864 benthic surveys, 432 coral surveys, 381 rugosity assessments, and 1,932 photo-transects within these 166 sites. The main challenges encountered were 1) rough seas and strong winds, and 2) unusually long transits from the M/Y Golden Shadow to survey locations because the anchorages for the M/Y Golden Shadow that were permitted by the GBRMPA were often a great distance away from the selected sites. As a result, 14 stations were not completed. This included two sites on Yule Detached Reef, two on Wood Reef, four on Eyrie, and two on UN 11-122. Also, UN 11-261 was eliminated because it was not representative or comparable to the

Fig. 1. Dive planning briefing. Photo by Yogi Freun.

matched pink and green zones. This reef was completely submerged with a poorly developed, algal-covered hard bottom at 17-25 m depth, minimal coral cover and structure, and an absence of a 10 m depth contour. Five Reefs was substituted for this site, but only two stations were completed.

General findings

Notable differences in fish, coral and benthic communities were observed between locations. These differences were most pronounced between reefs, but not necessarily between different management zones within each triplicate reef system. For instance, major differences were noted in the species diversity, abundance and size structure of reef fish and corals between inner, mid-shelf and outer reefs, between leeward and windward reefs within an individual reef, and between the most northern sites and sites extending from Lizard Island to the south.

1) Shark and Pelagic surveys

A preliminary total of 326 sharks (8 species) and 21 rays (4 species) were recorded along 121 belt transects. Most sharks were from the family Carcharhinidae, and included the blacktip reef shark (*Carcharhinus melanopterus*), the grey reef shark (*C. amblyrhynchos*), the silvertip shark (*C. albimarginatus*) and the whitetip reef shark (*Triaenodon obesus*). Other species sighted include the scalloped hammerhead (*Sphyrna lewini*), the tawny nurse shark (*Nebrius ferrugineus*), the epaulette shark (*Hemiscyllium* sp) and the Zebra shark (*Stegostoma fasciatum*). Grey reef sharks were the most abundant species, followed by whitetip reef sharks.

Fig. 2. Two gray reef shark (*Carcharhinus amblyrhynchos*).

Reef shark abundances were elevated in almost all reef zones when compared with previous surveys of Robbins et al (2006). This trend was consistent in all but one of the reef zones surveyed, and the only exception (whitetip reef sharks in Preservation Zones) was not significantly different from the findings from a decade ago. This is a very encouraging result, and suggests that changes to reef zones and shark fishing regulations made in 2004 and 2008, respectively, are having a positive effect. Most of the sharks sighted were immature individuals, indicating elevated survival of the younger cohorts.

A total of 2261 pelagic fishes were counted along the 145 belt transects, with 53% sighted on the outer reef and 47% on the mid-shelf. There were 20 species of pelagic fishes identified, with trevally and mackerel/tuna both similarly numerically dominant. Barracuda contributed 4% of the pelagic sightings. All pelagic groups were found to occur in large schools, as well as single individuals. Pelagic fish distribution showed patterns with shelf position more so than with reef zonation. More trevally were counted on outer reefs than on the mid-shelf, while a greater number of mackerel/tuna were sighted on the mid-shelf reefs.

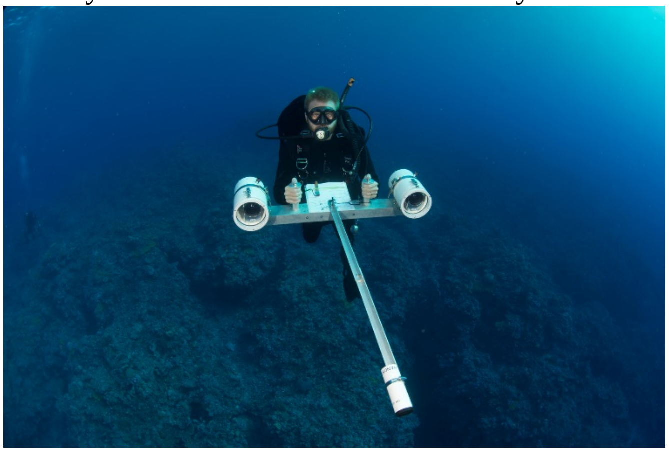


Fig. 3. Camera set-up used to collect stereo video images of sharks, pelagic species and other reef fish. Photo by Yogi Freun.

2) Reef fish surveys

A total of 510 species were recorded overall on all reefs. The most notable differences zones in fish species richness and biomass occurred between blue zones and green/pink zones, while green and pink zones were more similar in fish structure.

- Most Blue Zone reefs had low fish species richness and counts. Notable exceptions were Jewell, Five Reef and UN 11-238. These had a high species richness and abundance of herbivores (especially surgeonfish *Ctenochaetus striatus* and *Acanthurus grammoptilus*).
- The Green Zone reefs had higher abundances of important predators (sharks, snappers, groupers) and herbivores (surgeonfish and parrotfish); occasional occurrence of semi-pelagic species such as jacks and trevallies; and more frequent sightings of sharks than Blue Zones.
- The Pink Zone reefs had a higher occurrence of large individuals and schools of fish. Sharks were frequently observed (grey reefs, whitetip, silvertip) at similar densities to Green Zones. These reefs had a high abundance of predators including a few exceptionally large individuals of groupers (*Cromileptes altivelis*, *Epinephelus malabaricus* and *Cephalopholis lanceolatus*) and sweetlips (*Plectorhinchus albovittatus*). Napoleon wrasse were also more abundant.

Reef fish species richness, diversity and abundance varied among reefs with some prominent differences between inner, mid-shelf and outer reefs.

- Inner reefs had the lowest abundance of fishes, except at some sites where dense aggregations of the bream *Lethrinus nebulosus* were observed.
- Mid-shelf reefs had higher diversity and abundance than the inner reefs. There were high occurrences of large fish species at mid-shelf reefs. Sightings of grey reef sharks (*C. amblyrhynchos*), whitetip sharks (*T. obesus*), as well as groupers (*Plectropomus leopardus* and *P. laevis*), Napoleon wrasse (*Cheilinus undulatus*) and snapper (*Lujanus bohar*) were quite common.
- Outer barrier reef fish assemblages were similar to the mid-shelf reefs with high numbers of sharks, and groupers and snappers and high abundances of herbivores such as surgeonfish and parrotfish at some sites.

Differences in fish community structure were observed along a gradient from south to north.

- Southern sites had the lowest abundance and diversity of reef fish, with the lowest abundance and biomass overall recorded at Hilder and Eyrie.
- Exceptions included: 1) groupers (*P. leopardus*), which were common at most sites, including some southern sites (especially Williamson and Lark and the leeward side of the Ribbon Reefs); 2) a school of over 100 individuals of bumphead parrotfish (*Bolbometopon muricatum*; some over 90cm TL) at Ribbon Reef 5; and 3) high numbers of snapper (*Lutjanus gibbus*) at Hicks Reef.
- Fish assemblages at the central and northern regions of the GBR appeared to be in better condition compared to the southern reefs. There were more frequent sightings of sharks (grey reef *C. amblyrhychos*, whitetip reef shark *T. obesus*, and silvertip sharks *C. albimarginatus*). Groupers were abundant (*P. leopardus, P. laevis*), as well as the Napoleon Wrasse *C. undulatus.*
- Wood Reef had the highest abundance and biomass of fish observed during the entire mission due primarily to the presence of large schools of jacks *Caranx sexfasciatus*, snapper *Macolor niger*, *Lutjanus biguttatus* and *L. bohar* and, surgeonfish *Naso hexacanthus*, barracuda *Sphyraena jello*, and goatfish *Mulloidichthys vanicolensis*, and numerous grey reef sharks.
- Very large aggregations of bream *L. nebulosus* were recorded at Milman and Parkinson.

Fig. 4. Large schools of barracuda were recorded at Wood Reef.

3) Coral assessments

Coral communities had the richest diversity and highest cover on the northernmost sites, between 11° and 13° south latitude, while many of the sites between 14-15° degrees south latitude were degraded. Damage in these southern sites was attributed largely to past and ongoing crown of thorns (COTS) predation (mid-shelf sites) and impacts from a recent storm. COTS were very rare on the outer reefs.

The highest coral cover was seen at shallow depths, often above the 10 m depth profile, while very little coral occurred in many locations (especially outer sites) below 15 m depth. There were notable exceptions to this on some of the northern sites, where prolific coral communities were found to 30 m depth or deeper.

Mid-shelf reefs tended to have a higher diversity of corals than outer reefs, yet the visibility was much lower.

On outer, windward reefs, the reef crest often consisted of a prominent, low rugosity, scoured hardground colonized primarily by crustose coralline algae and turf algae, with and high cover of low-relief acroporids (especially *Acropora palifera*) and thick branched *Isopora* colonies at the edge of the reef slope. The reef crest and shallow fore reef slope often had large areas dominated by encrusting *Millepora* and leather corals (*Sarcophyton* and *Sinularia*). Coral cover tended to be highest from 5-8 m, then it quickly dropped on the fore reef slope. These reefs tended to have a near vertical slope extending to 30+ meters with little macroalgae and low cover of corals.

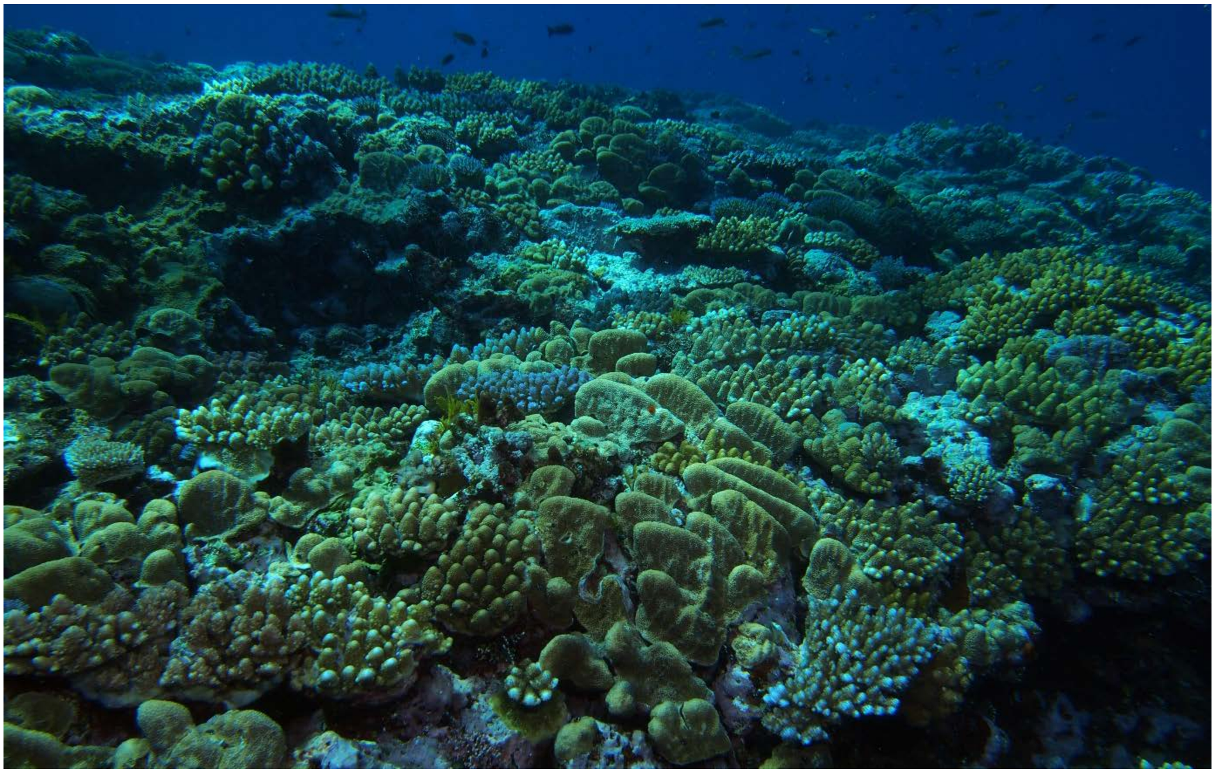


Fig. 5. Reef crest environment on the fore reef of Yonge Reef.

Fig. 6. Shallow fore reef slope at UN Reef 13-061.

Mid-shelf reefs in the central and northern sector often had large monospecific assemblages of corals in shallow water (3-10 m). These often formed large spheroid mounds several meters in diameter and height, with one colony coalescing with the neighboring colonies. Dominant species in these assemblages included *Porites cylindrica, Leptoseris gardeneri, Pachyseris rugosa, Pavona cactus, Porites rus, Paraclavarina,* as well as areas dominated by large massive *Porites lobata*.

Deeper reef communities on mid-shelf reefs in the northern sector often consisted of extensive overlapping shingles of foliaceous *Turbinaria, Pachyseris, Leptoseris, Merulina*, and *Echinopora* along with lower-relief *Goniopora* meadows. These occurred at very high cover (60-80%) between 10-20 m depth and occasionally were found much deeper.

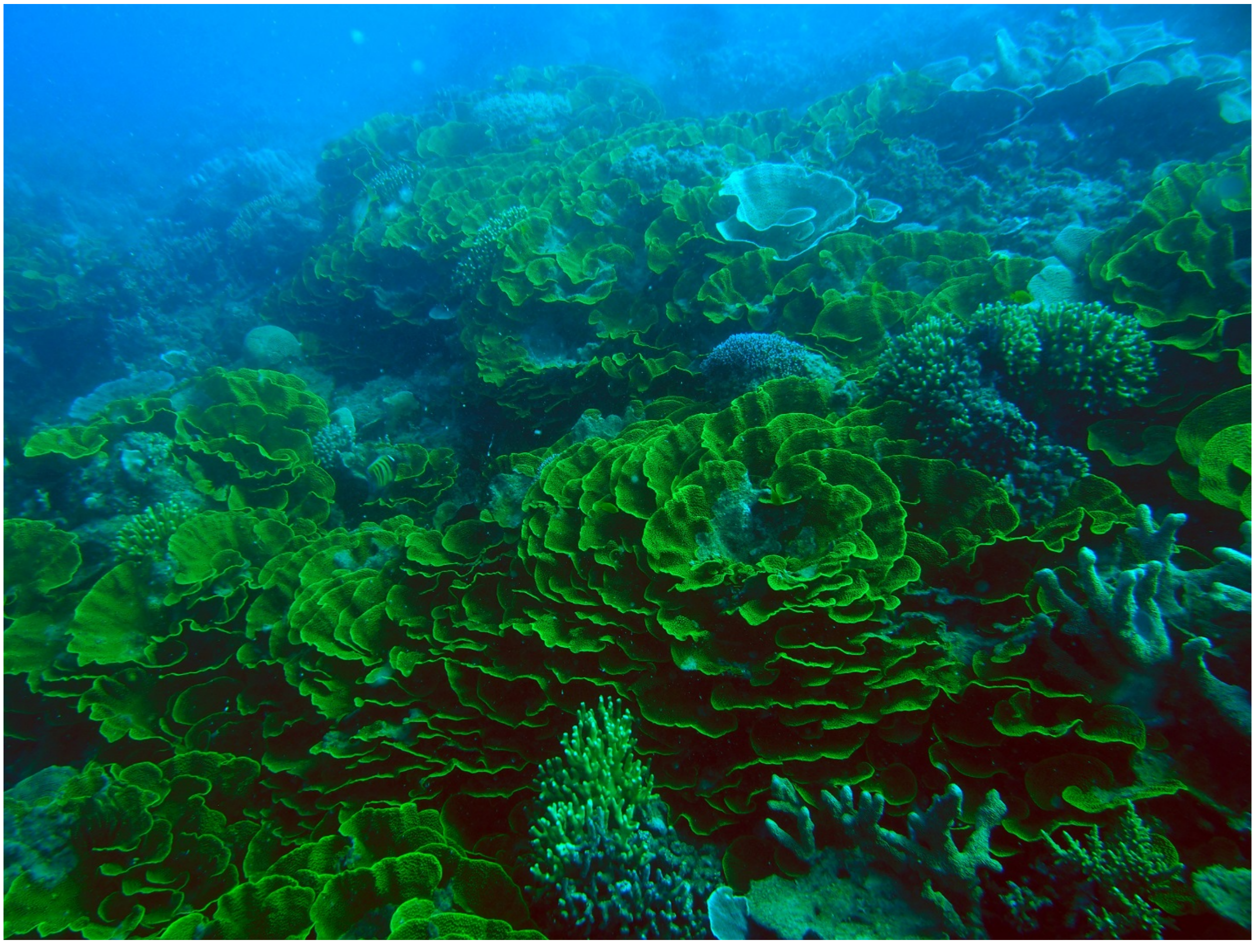


Fig. 7. Typical mid shelf reef at 20 m depth.

On mid-shelf reefs south of Lizard Island with active outbreaks of *Acanthaster*, the COTS had eaten most of the preferred species, such as branching *Pocillopora* and *Acropora*, plates of *Montipora* and plates of *Echinopora*, and they were seen consuming massive *Porites* colonies and other less-preferred species. One of the dominant corals remaining on damaged reefs was *Porites lichen*.

Colonies of *Seriatopora hystix* and *S. caliendrum* were in poor shape in most locations. Many colonies were bleached, exhibited signs of white syndrome, and had recently died and were covered in fine filamentous algae. Disease were rare on other species, with exception of white syndrome on table acroporids (Fig. 8) and staghorn corals.

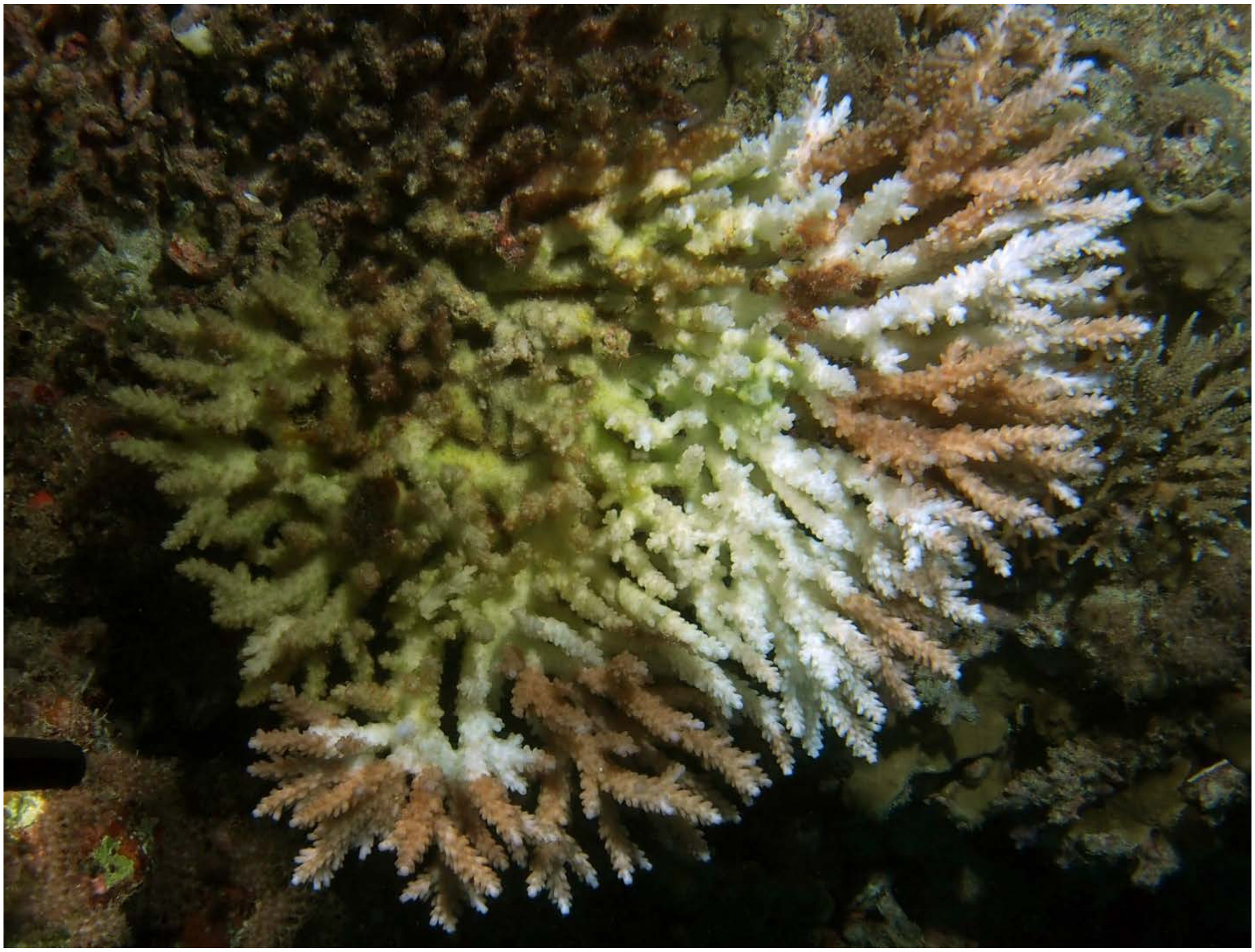


Fig. 8. Table acroporid with white syndrome.

4) Benthic communities

Most reefs had very low cover of macroalgae. One exception was the mid-shelf reefs in the south where clumps of red gelatinous algae such as *Liagora* and large mats of *Rosenvingea, Padina, Caulerpa,* and other species were common. Tufts of *Chlorodesmis* were found on many outer reefs and windward sites, but cover was generally less than 1%. Deeper sites and vertical walls also had encrustations of *Peysonnellia*. *Halimeda* was uncommon in most locations, except UN 11-025, Wood, Yule Detached, Hicks and Pearson.

Most reefs had 20-30% cover of turf algae, with higher cover and more dense turf with sediment on mid-shelf reefs in the south. Differences in algal cover did not appear to be related to management zones, but rather exposure and location.

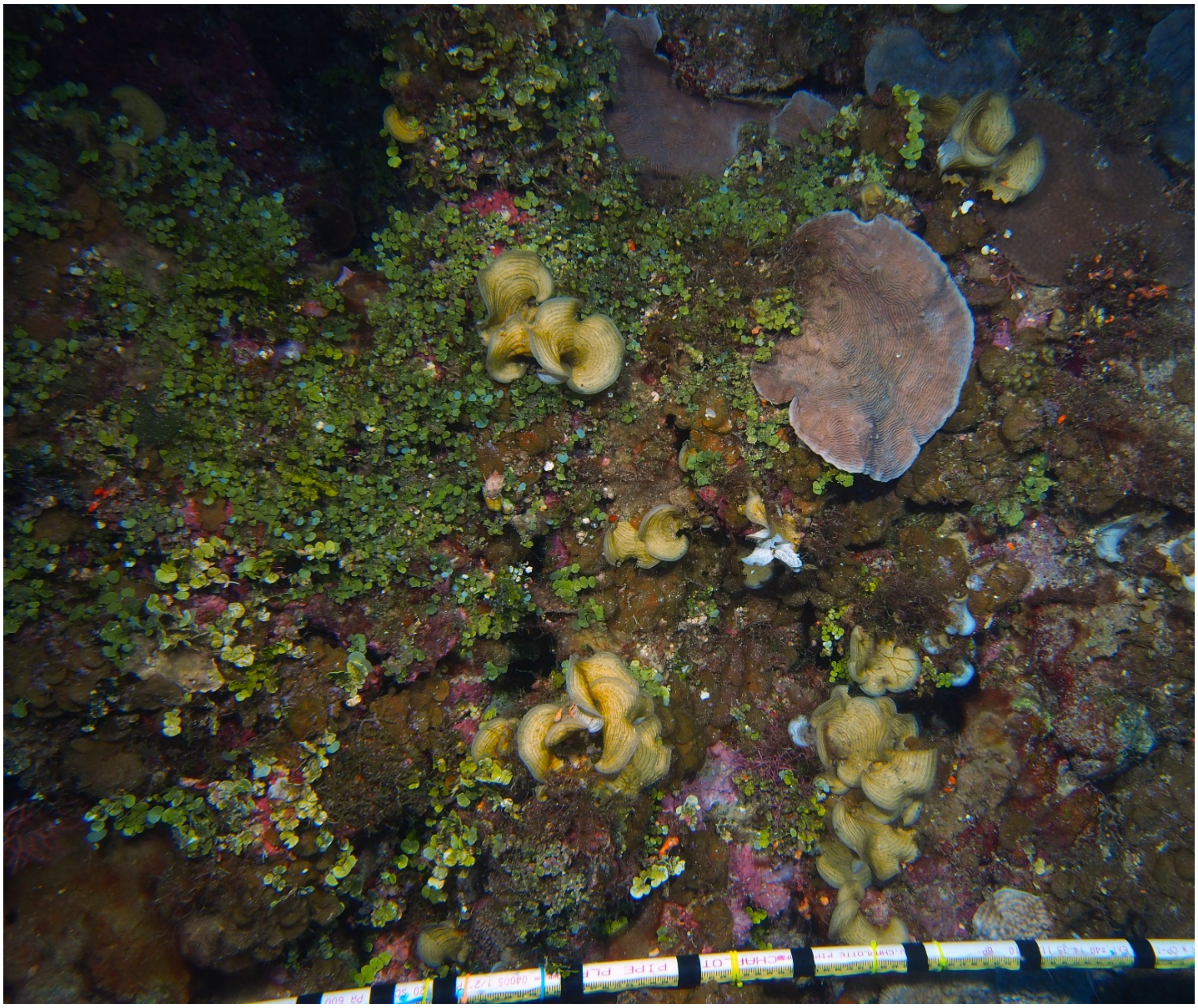


Fig. 9. Macroalgae (e.g. *Lobophora* and *Padina*) and erect coralline algae (*Halimeda*) occurred on most reefs at very low cover. Exceptions included Yule Detached Reef (shown here) and a few other locations.

A high diversity and abundance of sea cucumbers were noted on most mid-shelf locations, with up to 8 species and dozens of individuals documented on a single reef. Many mid-shelf reefs also had unusually large (>1 m) *Tridacna gigas* giant clams. Lobsters were rare; less than 10 were seen on the entire mission.

High numbers of *Diadema* were seen on Parkinson, UN 11-039 and Milman/Alpin reefs.

Accumulations of rubble and overturned corals were noted at several sites in the central GBR, especially reefs near Lizard Island. This was less common on windward outer reefs and northern reefs.

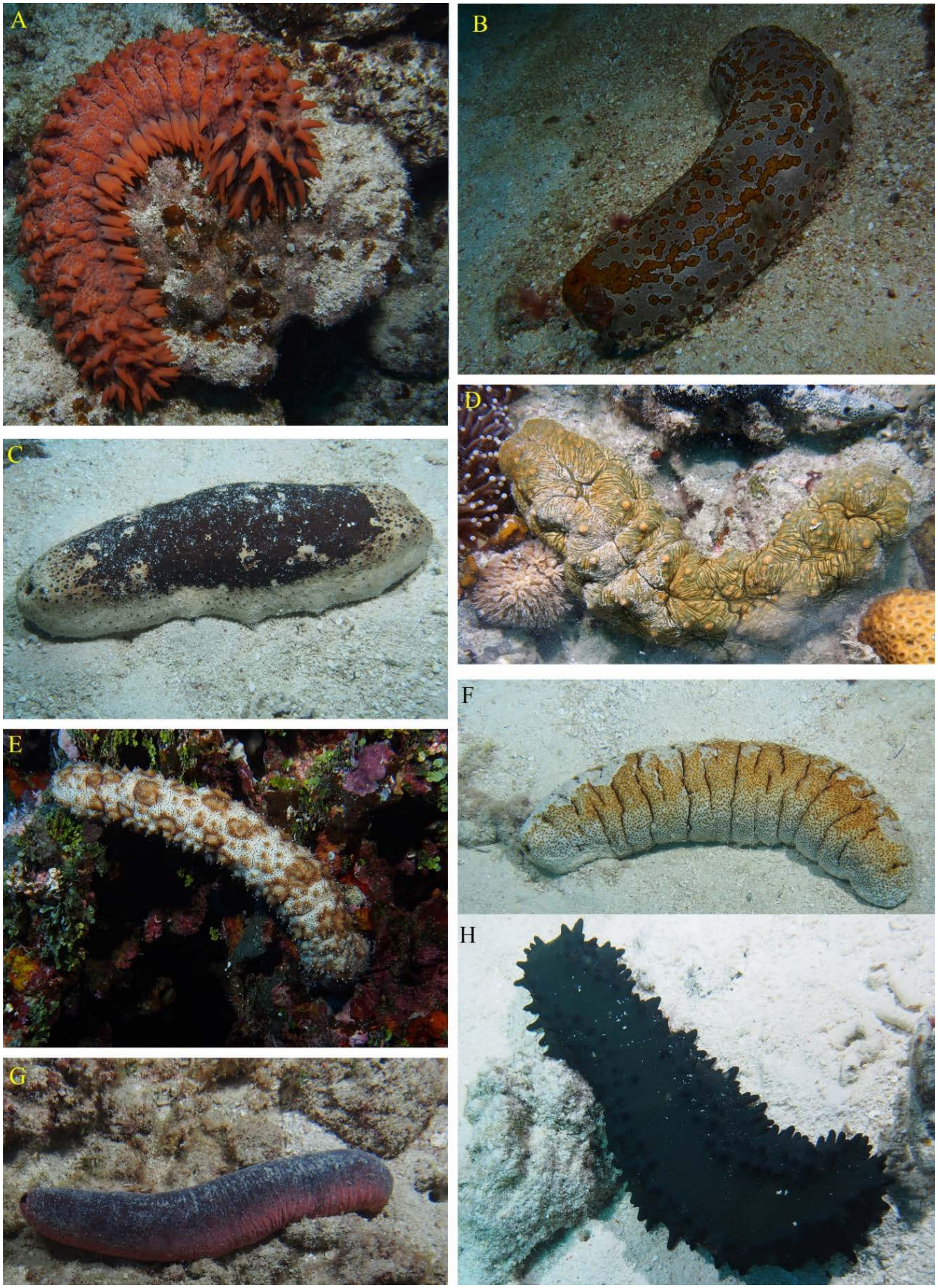


Fig. 10. Common sea cucumbers observed during the GBR mission. ***A. Thelenota ananas. B. Bohadschia argus. C. Holothuria fuscogilva D. Stichopus vastus. E. Pearsonothuria graeffei. F. Holothuria fuscopunctata. G. Holothuria edulis. H. Stichopus chloronotus*.**

Introduction

The Great Barrier Reef, Australia is recognized as one of the largest and best managed marine parks in the world. Nevertheless, there is evidence that some of the reefs within the park are undergoing a precipitous decline (Bellwood et al. 2004, Sweatman et al. 2011). Most recently, a scientific consensus statement reports declines of coral cover from around 50% in the 1960s to approximately 28% in 1985 and 14% in 2013 (Brodie et al. 2013). Changes in reef health have been attributed primarily to land-based stressors (e.g. increased discharge of sediments, nutrients and pesticides) which are compounding natural stressors and the effects of climate change (e.g. unusual rainfall events, more frequent and severe bleaching, increased severity and prevalence of coral diseases, outbreaks of crown-of-thorns seastars, and cyclones) (Sweatman et al. 2008).

Coral losses appear to have affected populations of certain corallivorous fishes most severely in the short term. In locations where recovery has been delayed, and there has been subsequent reductions of topographic complexity, researchers have reported reductions in the overall abundance and diversity of other species of small-bodied reef fishes that rely on the coral for food and shelter (Cheal et al. 2008; Pratchett et al. 2008). Increased pressure from commercial and recreational fisheries during the 1990s and early 2000s has also reduced the numbers and sizes of apex predators, especially *Plectropomus* spp., certain *Lutjanus* spp. and sharks (Ayling and Choat 2008; Goggin et al. 2002; Robbins et al. 2006). To reduce overfishing and rebuild exploited populations, additional regulations on commercial and recreational fishing were promulgated, and a revised zoning system was implemented in 2004 that now protects over 33% of the Great Barrier Reef Marine Park (GBRMP) through no-take zones.

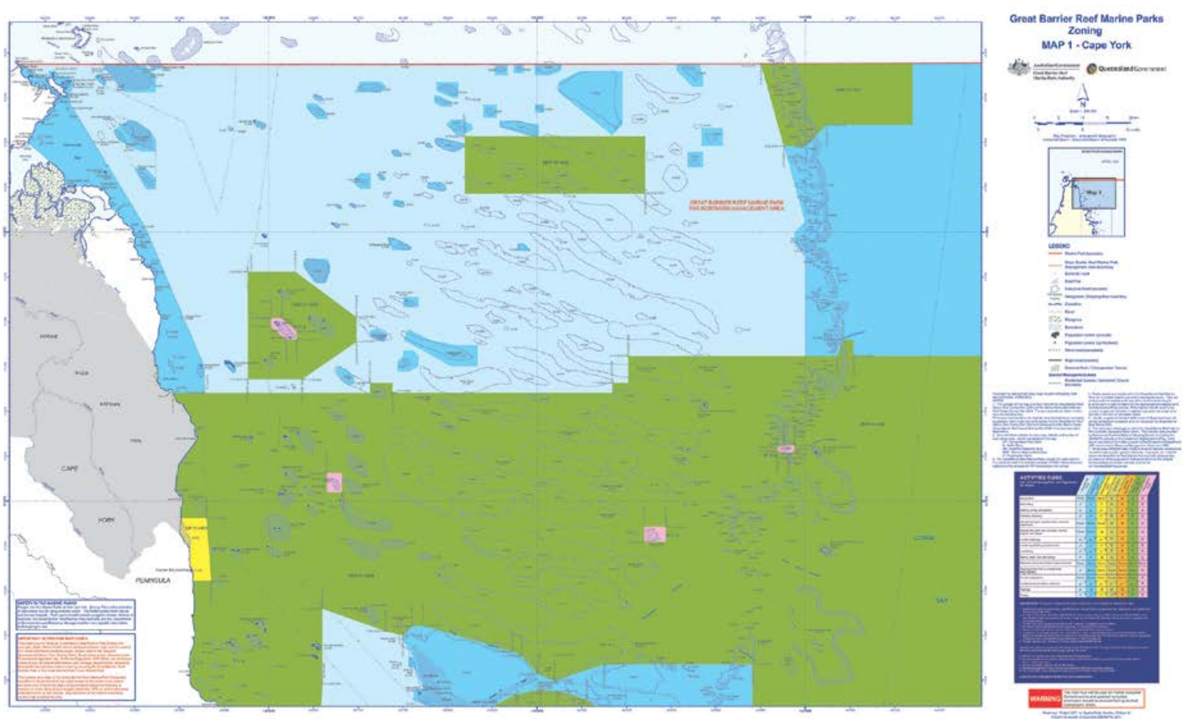


Fig. 11. Map 1 of the Great Barrier Reef Marine Park illustrating the Blue, Green and Pink Zones.

Numerous studies have suggested that intact ecosystems provide the best insurance against catastrophic acute impacts. Nevertheless, the importance of apex predators in enhancing reef resilience is not fully understood. This study seeks to improve our understanding of the condition of coral reefs and reef fish assemblages and the role of apex predators in maintaining healthy coral reef ecosystems through a comparative study of fished Habitat Protection Zone (Blue Zones), no-take Marine National Park Zone (Green Zones) and no-take, no entry Preservation Zone (Pink Zones) in the northern sector of Great Barrier Reef.

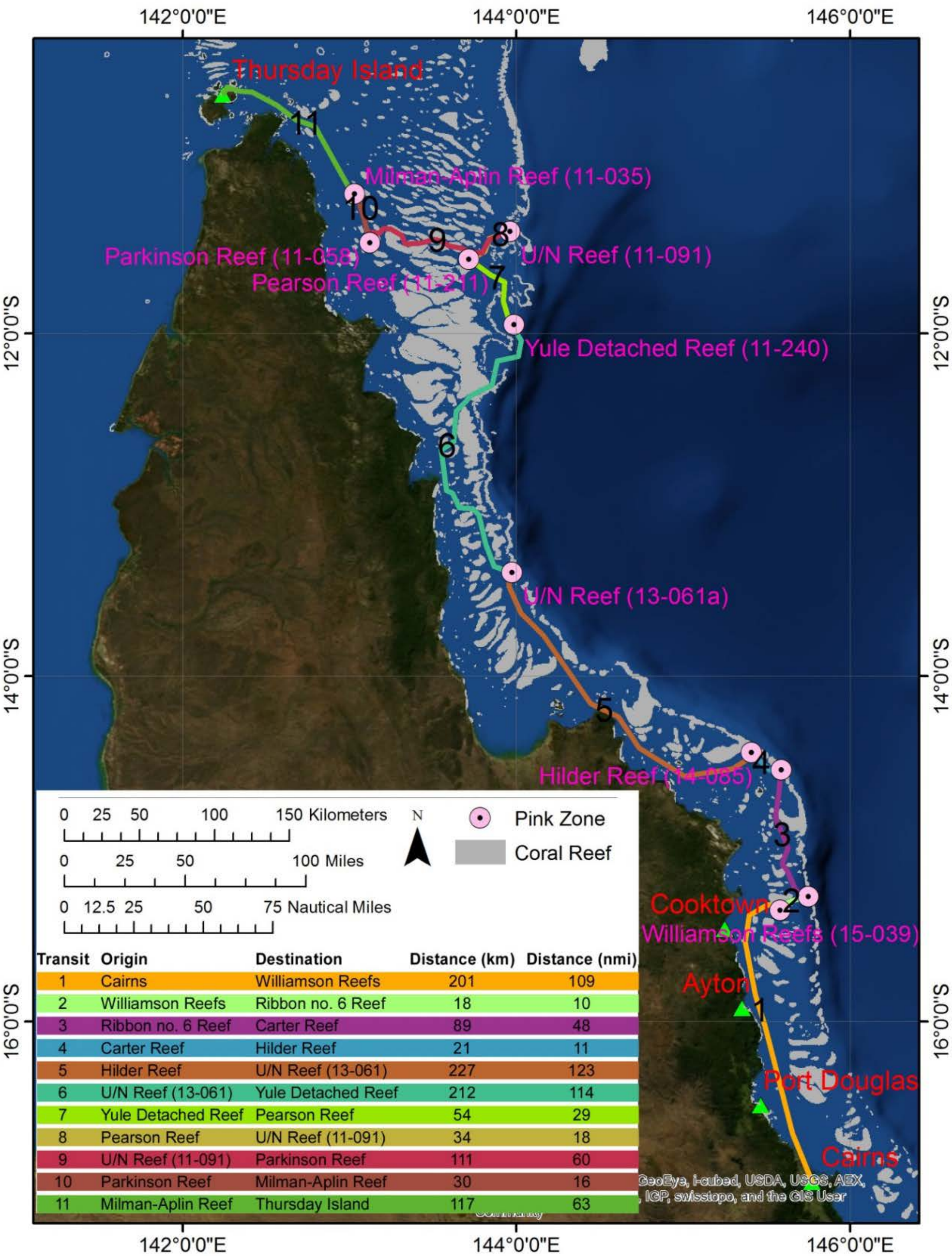
Specifically we sought to:

- Determine the value of Pink Zones in protecting apex predators;
- Characterize the health of coral reefs and differences in coral reef community structure between Pink, Green and Blue Zones in remote locations of the GBR;
- Improve our understanding of the linkage between the protection of exploited predators and the maintenance of ecosystem structure and function; and
- Determine the benefits of protection of exploited species in enhancing reef resilience.

During the month long mission we compared coral reef community structure between 30 reefs in a triplicate experimental design, divided into 10 Blue Zones, 10 Green Zones and 10 Pink Zones in the remote northern sector of the GBR, using a combination of point intercept surveys, belt transects and long distance swims. Our surveys focused on:

1) the benthic community structure (cover of corals, algal functional groups and other invertebrates;
2) habitat characteristics including rugosity;
3) the population dynamics (size structure) and condition of reef building corals;
4) impacts of coral disease, crown of thorns predation and recent storms on coral health and reef structure;
5) reef fish diversity, abundance and size structure; and
6) abundance and size structure of sharks and pelagic species.

We used a stratified random sampling design to survey 10 matched Blue, Pink and Green Zones, with 2-3 leeward and 2-3 windward sites per reef. Reef surveys were concentrated at 10 m depth, with additional data on benthic community structure collected from 5-30 m depth.



Transit	Origin	Destination	Distance (km)	Distance (nmi)
1	Cairns	Williamson Reefs	201	109
2	Williamson Reefs	Ribbon no. 6 Reef	18	10
3	Ribbon no. 6 Reef	Carter Reef	89	48
4	Carter Reef	Hilder Reef	21	11
5	Hilder Reef	U/N Reef (13-061)	227	123
6	U/N Reef (13-061)	Yule Detached Reef	212	114
7	Yule Detached Reef	Pearson Reef	54	29
8	Pearson Reef	U/N Reef (11-091)	34	18
9	U/N Reef (11-091)	Parkinson Reef	111	60
10	Parkinson Reef	Milman-Aplin Reef	30	16
11	Milman-Aplin Reef	Thursday Island	117	63

Fig. 12. Approximate route of the M/Y Golden Shadow during the GBR Expedition. The M/Y Golden Shadow followed the transit route and anchor locations approved by the Great Barrier Reef. To accommodate the approved passage plan, challenges with weather, and a change-out midway through the mission, the sites were not visited in the order listed above. Table 1 lists the final schedule of surveys.

Table 1. Final research Schedule undertaken between September 1- October 3, 2014.

Mon	1	**Scientists join in Cairns**	
Tues	2	**Checkout dive**	
Tues	2	**Transit overnight to Anchorage 1A.**	
Wed	3	Anchorage 1A	**Ribbon No 7 Reef (15-026)**
Thu	4	Anchorage 1A	**Ribbon No 6 Reef (15-032)**
Fri	5	Anchorage 1A	**Ribbon No 5 Reef (15-038)**
Sat	6	Anchorage 1A	**Lark Reef (15-033)**
Sun	7	Anchorage 1A-1B	**Williamson Reef (15-039)**
Mon	8	Anchorage 1B	**UN Reef (15-043)**
Tue	9	Anchorage 2	**Yonge (14-138)**
Wed	10	Anchorage 2	**Hicks Reef (14-086)**
Thu	11	Anchorage 2	**Carter Reef (14-137)**
Fri	12	Anchorage 2	**Jewell / Parke Reef**
Sat	13	Anchorage 3B	**Parkinson Reef (11-058)**
Sun	14	Anchorage 4	**UN Reef (13-061a)**
Mon	15	Anchorage 4	**UN Reef (11-039)**
Tue	16	**Change out - Horn Island. No diving**	
Wed	17	Anchorage 5	**UN Reef (11-025)**
Thu	18	Anchorage 5	**UN Reef (11-034)**
Fri	19	Anchorage 5	**Milman / Aplin Reef (11-035)**
Sat	20	Anchorage 5	**Monkman Reef (11-059)**
Sun	21	Anchorage 6	**Wood Reef (11-228)**
Mon	22	Anchorage 6	**Yule Detached Reef (11-240)**
Tue	23	Anchorage 6	**UN Reef (11-091)**
Wed	24	Anchorage 7	**UN Reef (11-096)**
Thu	25	Anchorage 7	**Pearson Reef (11-211)**
Fri	26	Anchorage 7	**Siddons Reef (11-200)**
Sat	27	Anchorage 7	**UN Reef (11-122)**
Sun	28	Anchorage 7	**UN Reef (11-238)**
Mon	29	Anchorage 3A	**UN Reef (13-116)**
Tue	30	Anchorage 3A	**Hilder Reef (14-085)**
Wed	1	Anchorage 2	**UN Reef (14-139)**
Thu	2	Anchorage 2	**Eyrie Reef (14-118)**
Fri	3	**Return to Cairns Marina. Scientist depart**	

Methods:

Study reefs

Thirty reefs were selected in the Far Northern Management Area of the Great Barrier Reef. Ten reefs were zoned Habitat Protection Zone (Blue Zone) and were open to line fishing, ten reefs were Marine National Park Zones (Green Zone) and were closed to fishing and ten reefs were Preservation Zones (Pink Zone) that are no - go zones closed for all activities except emergency anchoring and a limited number of permitted research programs (Table 1). An attempt was made to select comparable survey reefs in triplicate, with each set including one Pink, Green and Blue Reef. Within each reef, a stratified random sampling plan was used to identify survey locations within leeward / NW reefs and windward reefs. For each reef, six locations were selected, with a total of 180 survey locations within the 30 reefs.

Shark and pelagic surveys

Reef shark and fish surveys were conducted following the protocols of Robbins et al (2006). Surveys involved swimming 400 m belt transects in 20 minutes on SCUBA, counting all sharks seen within 10 m of the line of travel. Following the findings of Robbins (2006), reef crest and reef pass habitats were surveyed as they provide the highest estimates of shark abundances. Lengths of survey transects were periodically verified with LOF boat staff and towed GPS units. The number of transects conducted was limited to two transects per dive due to constraints on maximum dive duration. All dives were recorded using a stereo camera rig, to allow later analysis of shark movements and sizes.

Fish Assessments

For fish, abundance and size structure was collected for over 400 species of fishes, 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 were 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. Additional phototransects were taken using a 1m X 1m quadrat which was placed on the substrate at a particular depth, and overturned ten times to obtain a continuous 1 X 10 m set of images.

Images were downloaded onto a computer, enhanced using Photoshop, and are being analyzed for 1) cover including benthic community composition, coral cover and cover of other organisms and substrate type, and 2) for coral abundance, condition and size structure (planar surface area) The analysis is conducted using Coral Point Count (CPCE) software developed by the National Coral Reef Institute (NCRI). Cover is determined by recording the benthic attribute located directly below random points (30-50 points per photograph). Planar surface area is 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 was 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.

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.

Table 2. Aerial coverage and number of surveys conducted on the Great Barrier Reef, Australia.

Distances from South to North	762 km.
Distances from East to West	103 km.
Latitudinal coverage	4°
Hours underwater (pooled for all divers)	3,416 hrs.
Number of reefs	30
Number of survey locations*	166
Fish transects	565
Benthic transects	864
Coral transects	432
Rugosity measurements	381
Photo transects	1,932
Number shark/pelagic surveys	145

- Does not include the sites examined by the shark team

Table 3. Coordinates of survey sites.

Date	Site	Lat	Lon	Zone
9/3/2014	AUR701	-15.207340	145.75415	Green
	AUR702	-15.223801	145.75116	Green
	AUR703	-15.207740	145.75432	Green
	AUR704	-15.193007	145.73312	Green
	AUR705	-15.202160	145.75308	Green
	AUR706	-15.222123	145.73912	Green
9/4/2014	AUR607	-15.267660	145.75757	Pink
	AUR608	-15.271960	145.75996	Pink
	AUR609	-15.292803	145.75196	Pink
	AUR610	-15.271410	145.75969	Pink
	AUR611	-15.281268	145.74229	Pink
	AUR612	-15.360560	145.78984	Blue
9/5/2014	AUR513	-15.383578	145.77395	Blue
	AUR514	-15.390990	145.78166	Blue
	AUR515	-15.349195	145.77886	Blue
	AUR516	-15.330390	145.77878	Blue
	AUR517	-15.292105	145.62526	Blue
	AUR518	-15.303980	145.60458	Blue
9/6/2014	AULK19	-15.275957	145.64843	Green
	AULK20	-15.267170	145.58049	Green
	AULK21	-15.367102	145.62004	Green
	AULK22	-15.358020	145.63112	Green
	AUWL23	-15.347986	145.55937	Pink
	AUWL24	-15.348230	145.59343	Pink
9/7/2014	AUWL25	-15.379330	145.58966	Pink
	AUWL26	-15.297680	145.52167	Pink
	AUWL27	-15.346593	145.52782	Pink
	AUWL28	-15.423590	145.54594	Pink
	AULK29	-15.274460	145.52433	Green
	AULK30	-15.444660	145.53088	Green
9/8/2014	AU4331	-15.405685	145.50404	Blue
	AU4332	-15.423590	145.54594	Blue
	AU4333	-15.404968	145.49327	Blue
	AU4334	-15.444660	145.53088	Blue
	AU4335	-15.436432	145.47730	Blue
	AU4336	-15.454050	145.50047	Blue
9/9/2014	AUYG37	-14.618851	145.61835	Green
	AUYG38	-14.583730	145.63033	Green
	AUYG39	-14.588835	145.61616	Green
	AUYG40	-14.604450	145.63245	Green
	AUYG41	-14.460674	145.51068	Green
	AUYG42	-14.474590	145.50357	Green
9/10/2014	AUHK43	-14.443989	145.49940	Blue
	AUHK44	-14.475670	145.50185	Blue
	AUHK45	-14.454845	145.46797	Blue
	AUHK46	-14.429180	145.45016	Blue
	AUHK47	-14.458000	145.51000	Blue
	AUHK48	-14.443470	145.45618	Blue
9/11/2014	AUCT49	-14.557928	145.58492	Pink
	AUCT50	-14.569640	145.60875	Pink
	AUCT51	-14.528056	145.56915	Pink
	AUCT52	-14.546060	145.60214	Pink
	AUCT53	-14.378774	145.39849	Pink
	AUCT54	-14.542510	145.57550	Pink
9/12/2014	AUJW55	-14.405616	145.38920	Blue
	AUJW56	-14.371370	145.38455	Blue
	AUJW57	-14.419480	145.36426	Blue
	AUJW58	-14.393500	145.40512	Blue
	AUPK59	-13.397119	143.96652	Blue
	AUPK60	-14.431800	145.34987	Blue

Table 3 (cont.). Coordinates of survey sites.

Date	Site	Lat	Lon	Zone
9/13/2014	AU61A61	-13.389331	143.95652	Pink
	AU61A62	-13.422440	143.98878	Pink
	AU61A63	-13.384430	143.96076	Pink
	AU61A64	-13.409820	143.99300	Pink
	AU61A65	-11.457946	143.12048	Pink
	AU61A66	-13.394470	143.98770	Pink
9/14/2014	AUPS67	-11.457946	143.12048	Pink
	AUPS68	-11.460554	143.12664	Pink
	AUPS69	-11.469078	143.11940	Pink
	AUPS70	-11.458810	143.12460	Pink
	AUPS71	-11.471000	143.13200	Pink
	AUPS72	-11.460330	143.11542	Pink
9/15/2014	AU3973	-11.246353	143.25690	Blue
	AU3974	-11.247690	143.26266	Blue
	AU3975	-11.239000	143.24900	Blue
	AU3976	-11.236440	143.24940	Blue
	AU2577	-11.051911	143.06939	Blue
	AU2578	-11.048680	143.08170	Blue
9/17/2014	AU3479	-11.154767	143.08721	Green
	AU3480	-11.169540	143.11365	Green
	AU3481	-11.186199	143.09603	Green
	AU3482	-11.160900	143.10164	Green
	AU3483	-11.180310	143.01891	Green
	AU3484	-11.194660	143.12039	Green
9/18/2014	AUMM85	-11.175772	143.03553	Pink
	AUMM86	-11.197480	143.03865	Pink
	AUMM87	-11.165772	143.00994	Pink
	AUMM88	-11.191260	143.04805	Pink
	AUMM89	-11.177000	143.01700	Pink
	AUMM90	-11.188000	143.02658	Pink
9/19/2014	AU2591	-11.086113	143.10767	Blue
	AU2592	-11.059580	143.11398	Blue
	AU2593	-11.066000	143.06900	Blue
	AU2594	-11.092890	143.09227	Blue
	AU3995	-11.455555	143.14064	Blue
	AU3996	-11.240090	143.26254	Blue
9/20/2014	AUMO97	-11.455555	143.14064	Green
	AUMO98	-11.486650	143.17015	Green
	AUMO99	-11.468127	143.14269	Green
	AUMO100	-11.474020	143.17414	Green
	AUMO101	-11.784711	143.96912	Green
	AUMO102	-11.479580	143.15117	Green
9/21/2014	AUWD103	-11.784711	143.96912	Green
	AUWD104	-11.810800	143.98236	Green
	AUWD105	-11.819854	143.98289	Green
	AUWD106	-11.813410	143.96620	Green
9/22/2014	AUYD107	-11.950835	143.97606	Pink
	AUYD108	-11.966250	143.99466	Pink
	AUYD109	-11.950456	143.97596	Pink
	AUYD110	-11.940030	143.99887	Pink
9/23/2014	AU91111	-11.403018	143.95555	Pink
	AU91112	-11.398590	143.96771	Pink
	AU91113	-11.399891	143.96171	Pink
	AU91114	-11.400610	143.95702	Pink
	AU91115	-11.403747	143.97031	Pink
	AU91116	-11.421090	143.97749	Pink
9/24/2014	AU96117	-11.429594	143.96692	Green
	AU96118	-11.421090	143.97749	Green
	AU96119	-11.421208	143.97081	Green
	AU96120	-11.430750	143.97054	Green
	AU96121	-11.421446	143.97005	Green
	AU96122	-11.423590	143.98235	Green

Table 3 (cont.) Coordinates of survey sites.

Date	Site	Lat	Lon	Zone
9/25/2014	AUPE123	-11.559704	143.71457	Pink
	AUPE124	-11.559020	143.71887	Pink
	AUPE125	-11.571585	143.71192	Pink
	AUPE126	-11.564300	143.72749	Pink
	AUPE127	-11.559704	143.71457	Pink
	AUPE128	-11.572930	143.72023	Pink
9/26/2014	AUSD129	-11.521080	143.65250	Green
	AUSD130	-11.520770	143.66670	Green
	AUSD131	-11.515637	143.65783	Green
	AUSD132	-11.521970	143.65906	Green
	AUSD133	-11.514260	143.65549	Green
	AUSD134	-11.515853	143.64772	Green
9/27/2014	AU122135	-11.200634	144.03882	Blue
	AU122136	-11.203640	144.05699	Blue
	AU122137	-11.189656	144.04725	Blue
	AU122138	-11.199420	144.05299	Blue
	AU5R139	-11.860472	143.84125	Blue
	AU5R140	-11.865530	143.84984	Blue
9/28/2014	AU238141	-11.919059	143.84117	Blue
	AU238142	-11.922070	143.85901	Blue
	AU238143	-11.909067	143.84699	Blue
	AU238144	-11.927350	143.84872	Blue
	AU5R145	-11.860472	143.84125	Blue
	AU5R146	-11.878310	143.83228	Blue
9/29/2014	AU74147	-13.497650	144.04908	Green
	AU74148	-13.456990	144.05675	Green
	AU74149	-13.482389	144.03206	Green
	AU74150	-13.473940	144.03493	Green
	AU74151	-13.498168	144.05065	Green
	AU5R152	-11.903846	143.82588	Green
9/30/2014	AU116153	-13.498880	144.06003	Blue
	AU116154	-13.517616	144.06563	Blue
	AU116155	-13.504400	144.08232	Blue
	AU116156	-13.538192	144.07604	Blue
	AU116157	-13.545710	144.10683	Blue
	AU116158	-13.559950	144.08046	Blue
10/1/2014	AUHI159	-13.605660	144.09070	Pink
	AUHI160	-14.440995	145.39494	Pink
	AUHI161	-14.430060	145.40298	Pink
	AUHI162	-14.458537	145.39797	Pink
	AUEY163	-14.425150	145.42642	Green
	AUEY164	-14.685157	145.38206	Green
10/2/2014	AUHI165	-14.440970	145.42638	Pink
	AUHI166	-14.464610	145.41194	Pink

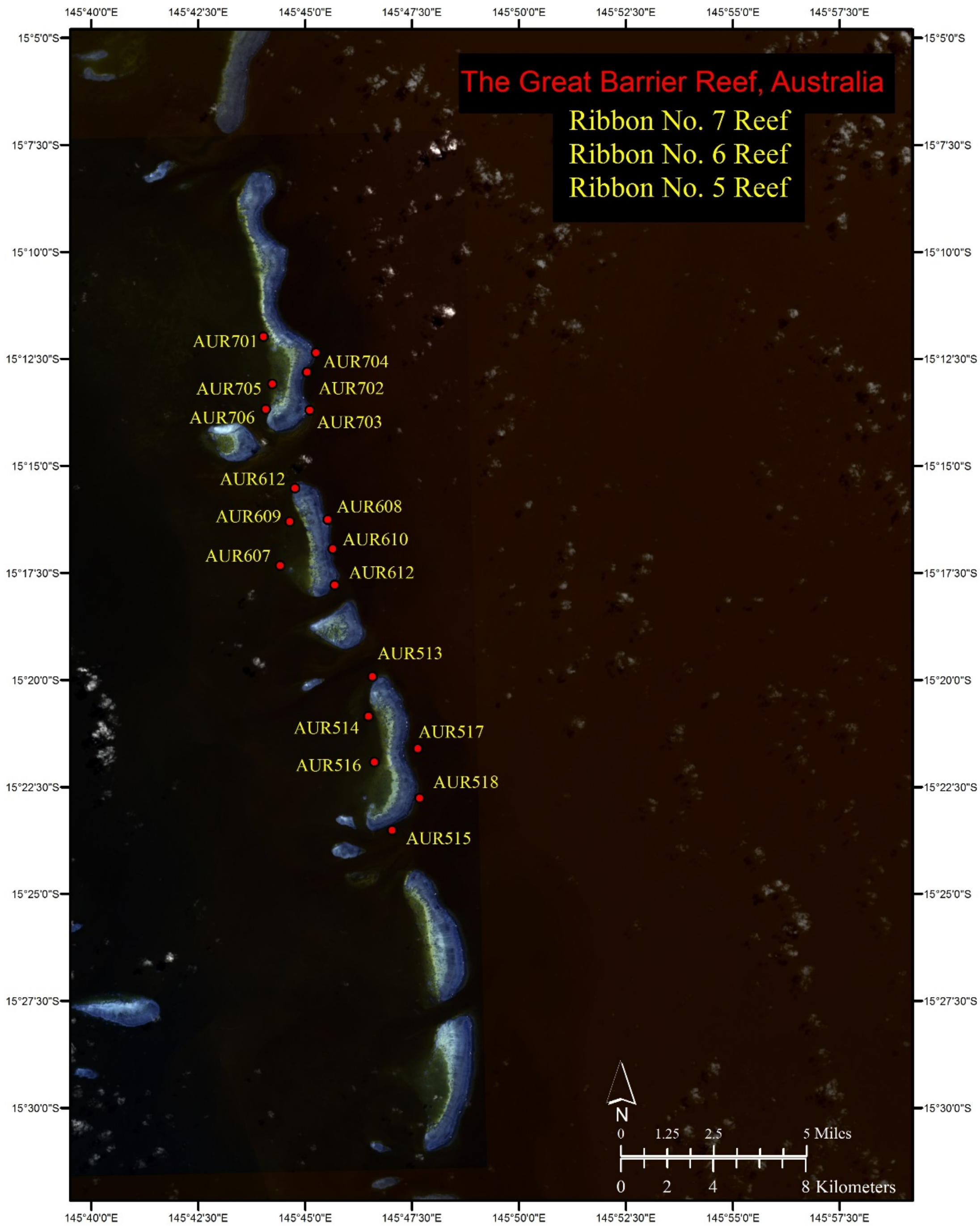


Fig. 13. Location of SCUBA assessments around Ribbon No. 5, 6 and 7 Reefs.

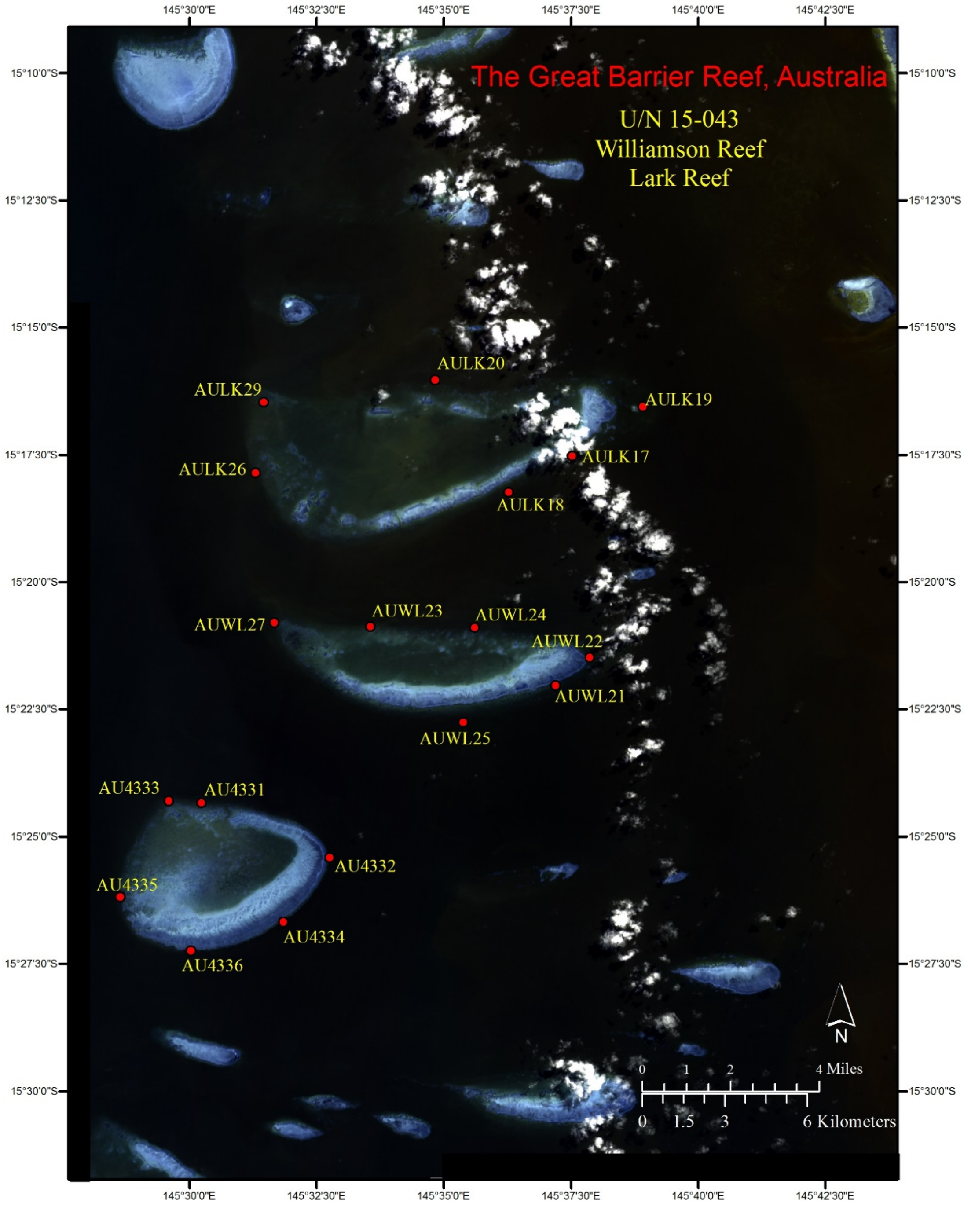


Fig. 14. Location of SCUBA assessments around UN 15-043, Williamson, and Lark.

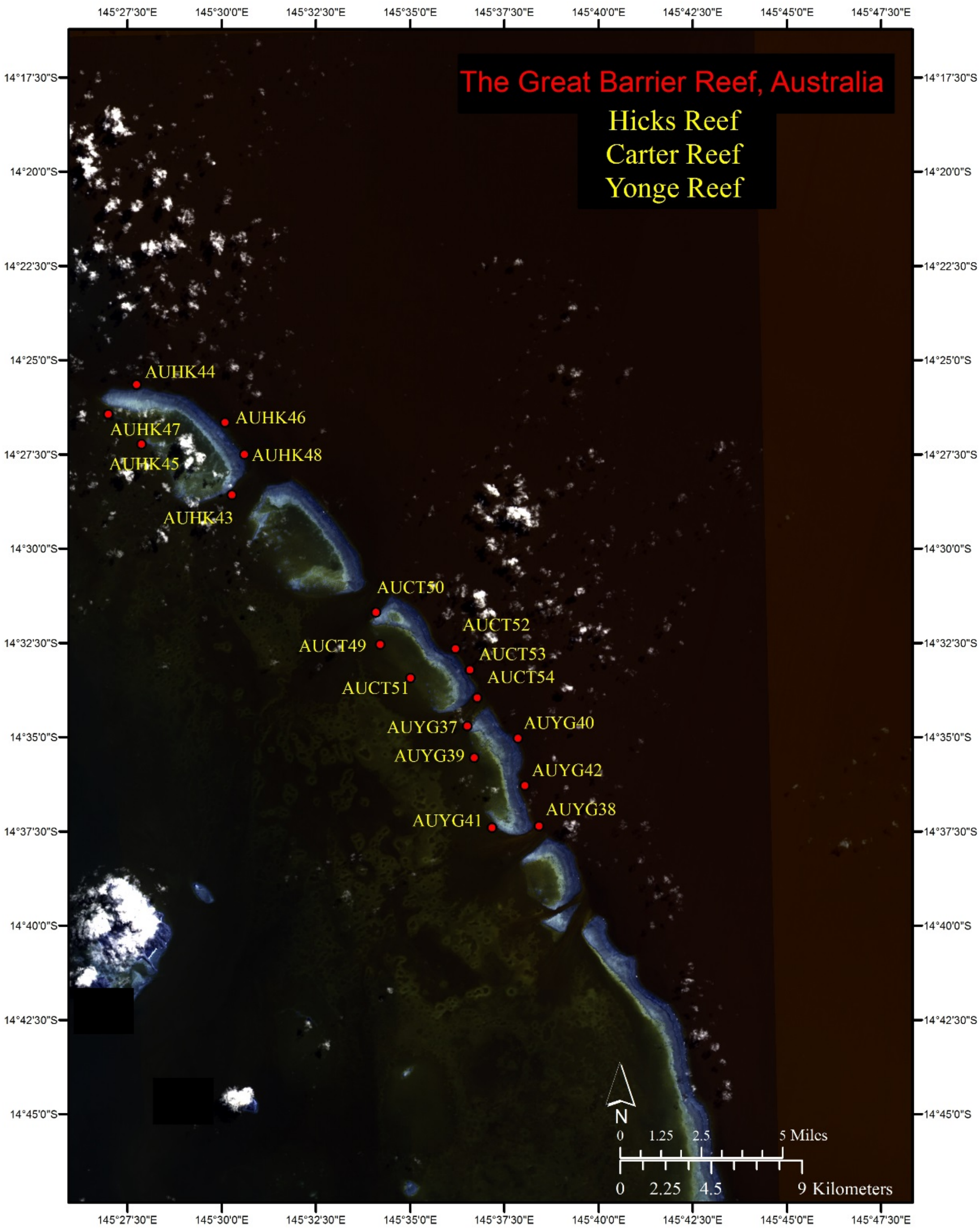


Fig. 15. Location of SCUBA assessments around Yonge, Hicks and Carter.

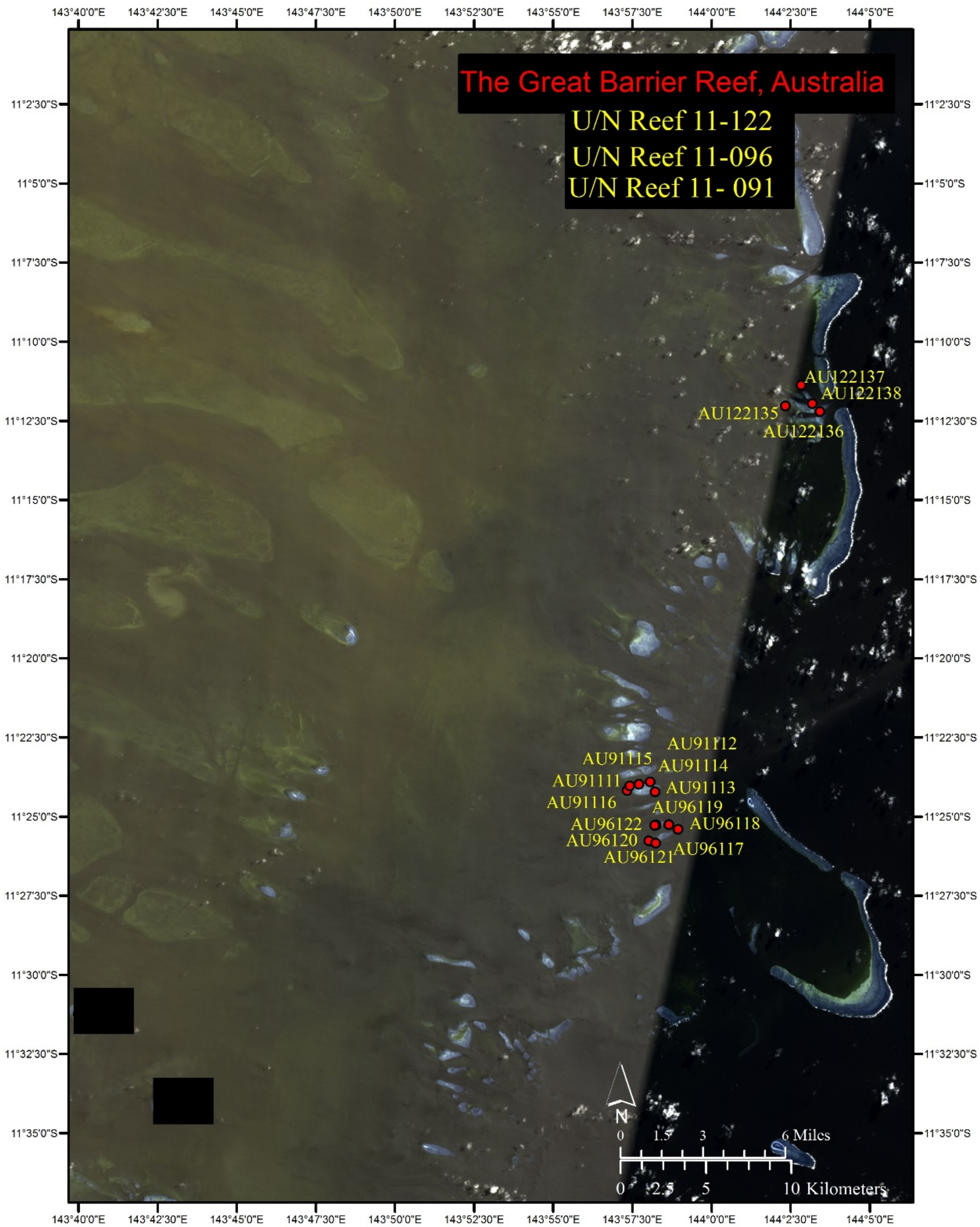


Fig. 16. Location of SCUBA assessments around UN 11-122, 11-096, 11-091.

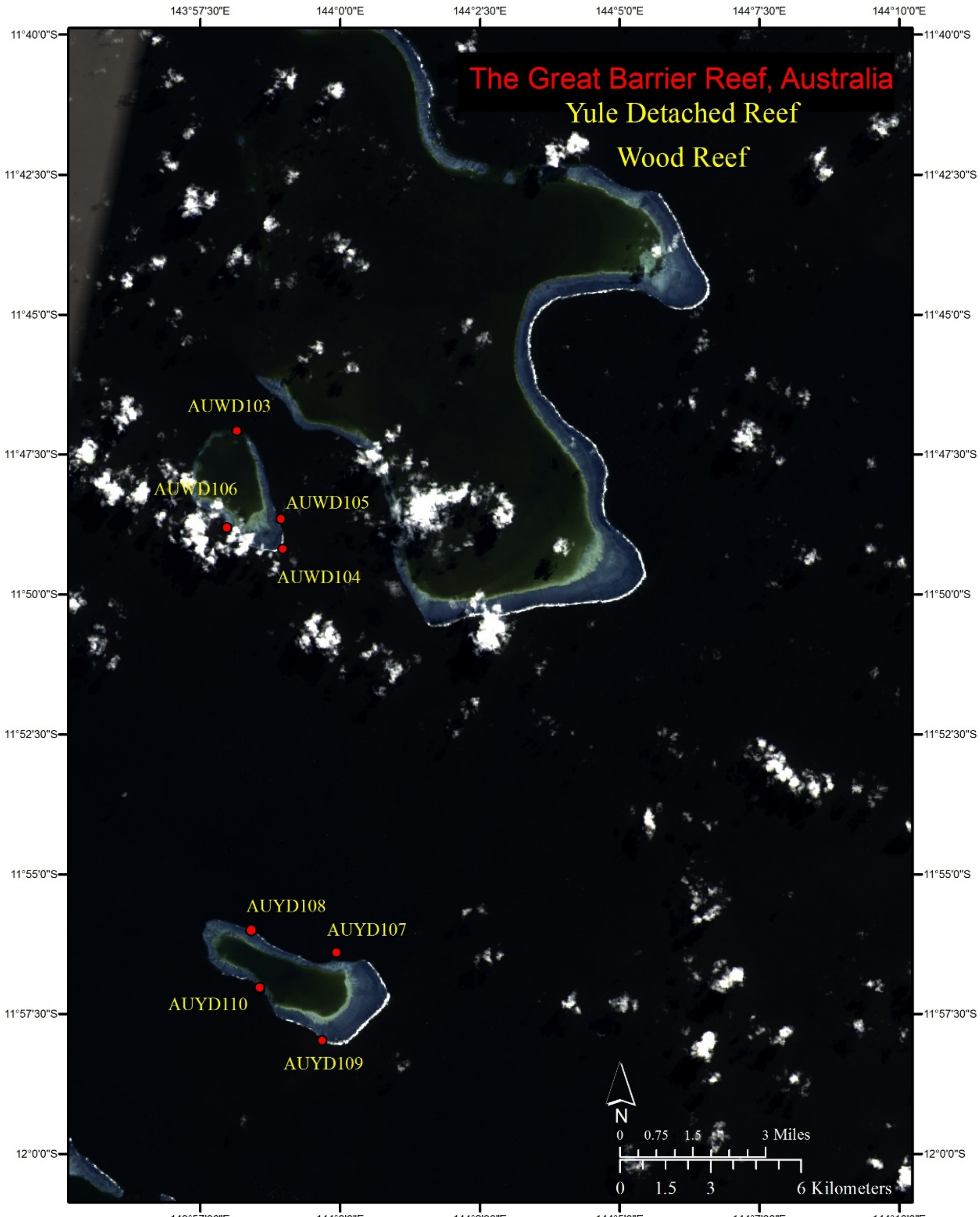


Fig. 17. Location of SCUBA assessments around Yule Detached Reef and Wood Reef.

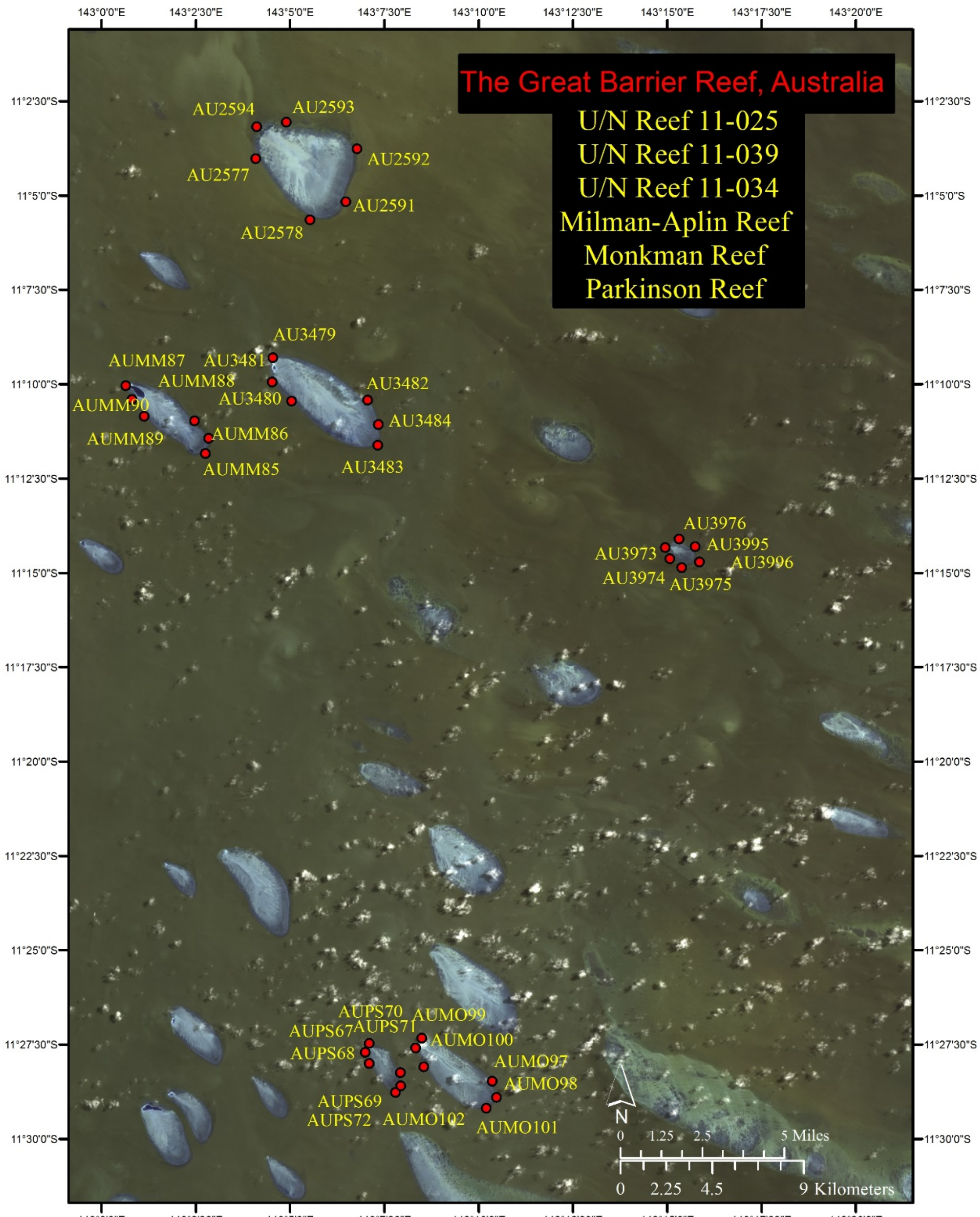


Fig. 18. Location of SCUBA assessments around Parkinson, Monkman, Milman-Alpin, UN 25, UN 34 and UN 39.

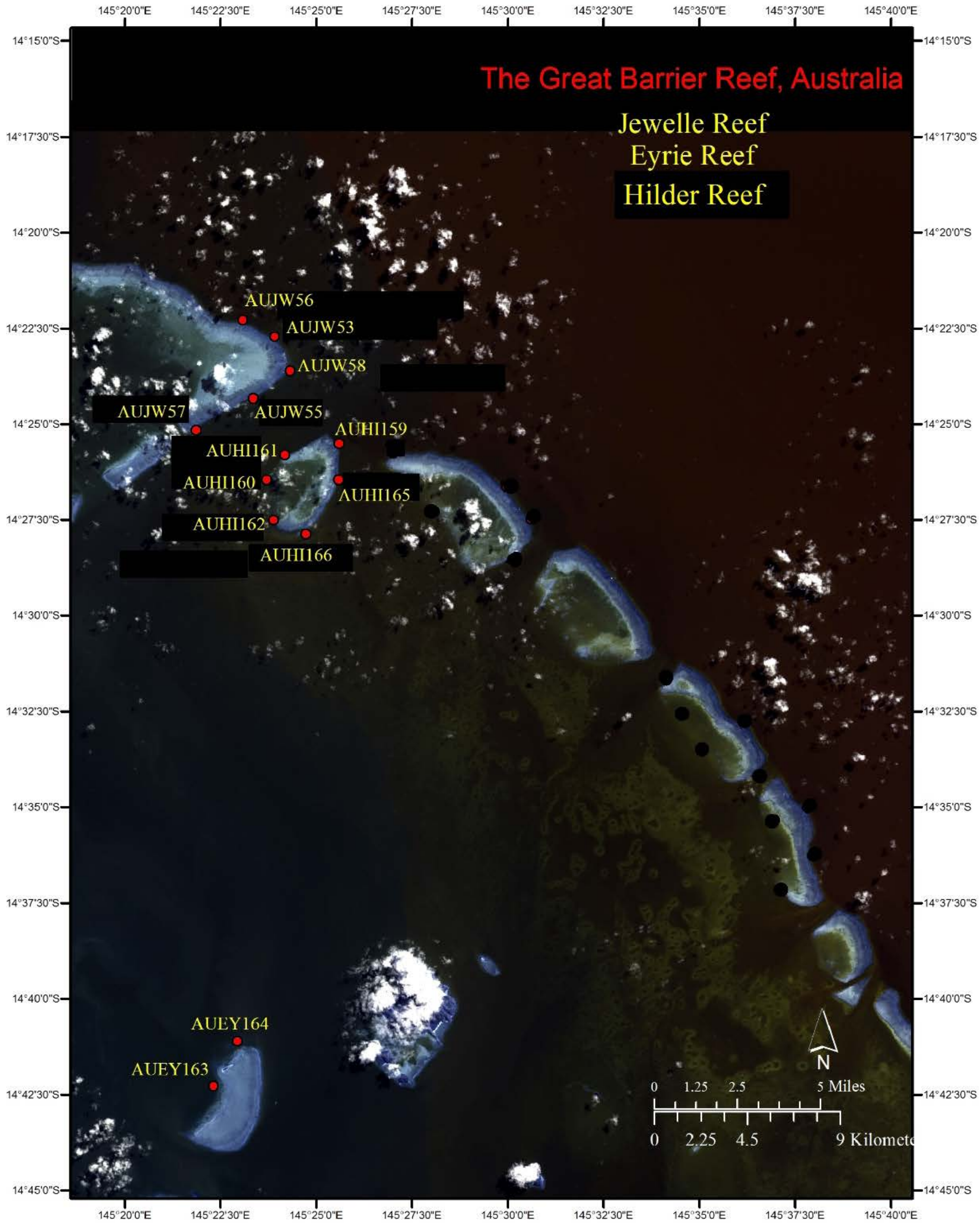


Fig. 19. Location of SCUBA assessments around Jewell, Eyrie and Hicks.

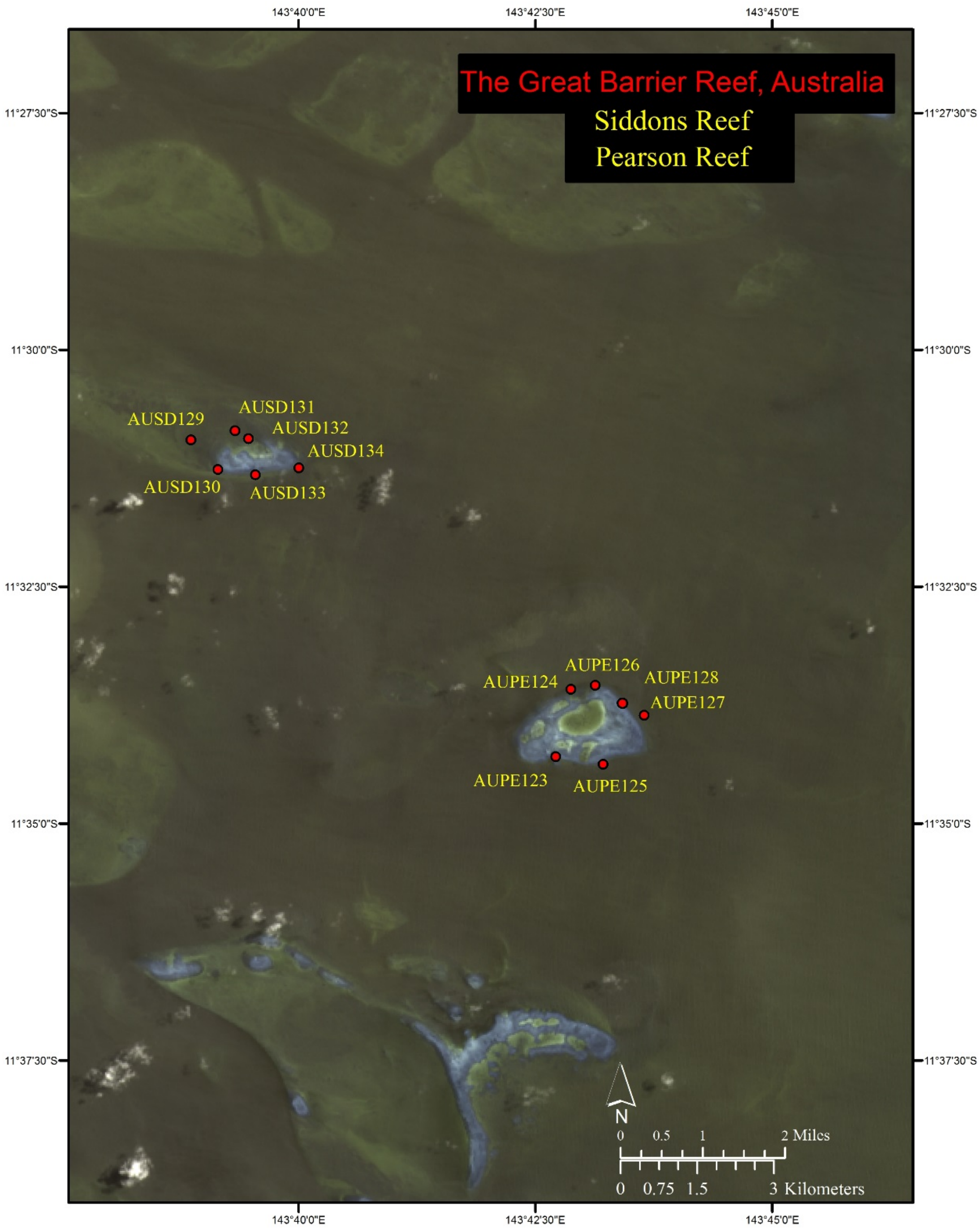


Fig. 20. Location of SCUBA assessments around Siddons and Pearson Reef.

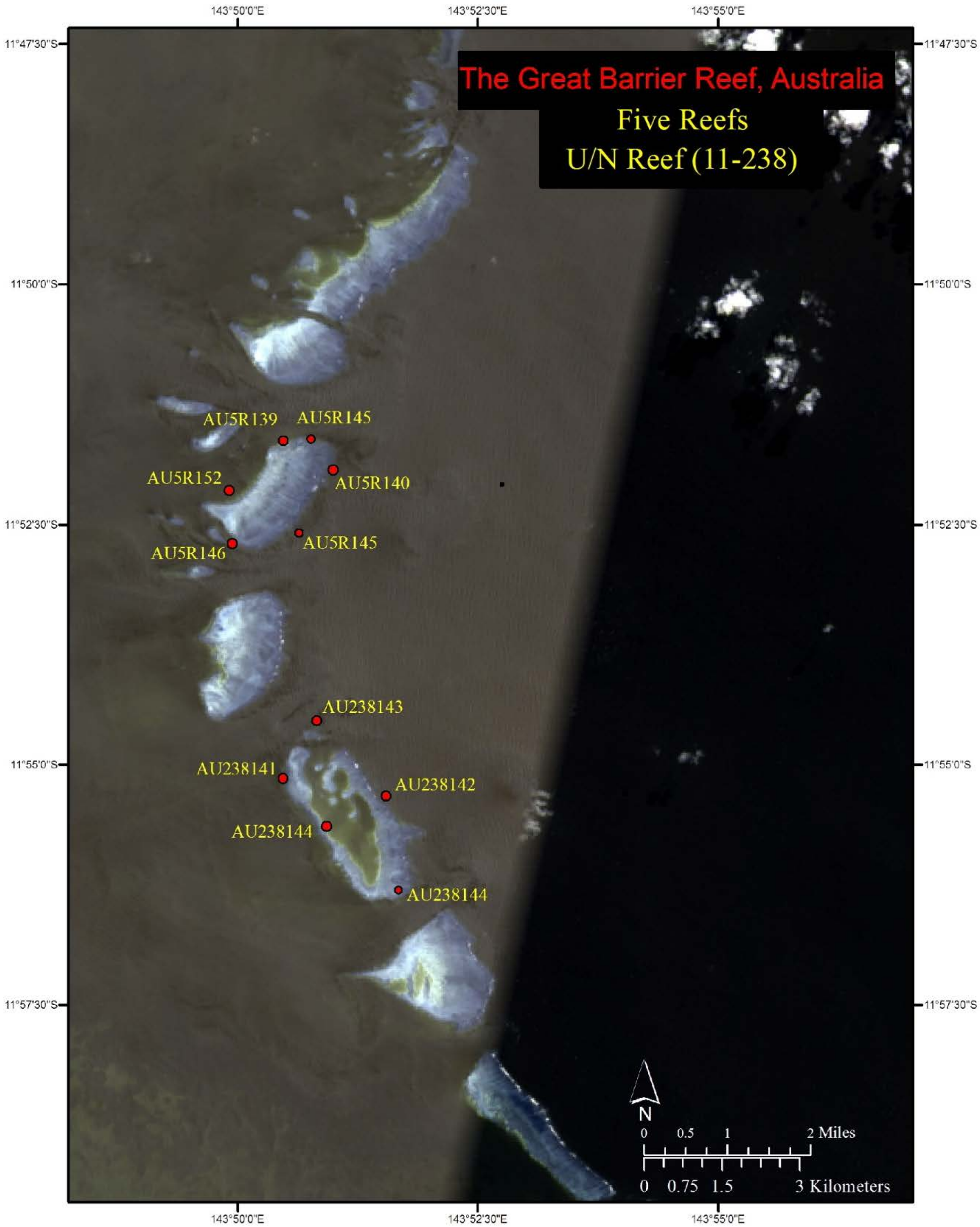


Fig. 21. Location of SCUBA assessments around Five Reefs and UN 11-238.

Appendix 1. Participants

Name	Institution	Role
Phil Renaud	Living Oceans Foundation	Executive Director
Andrew Bruckner	Living Oceans Foundation	Lead PI, Coral
Alex Dempsey	Living Oceans Foundation	Benthic
Anderson Mayfield	Living Oceans Foundation fellow	Rugosity
Ken Marks	Atlantic and Gulf Reef Assessment (AGRRA)	Phototransects
Grace Frank	James Cook University	Coral
Badi Samaniego	University of Philippines	Fish
Samantha Clements	Scripps Institution of Oceanography	Benthic
Katie Lubarsky	University of Hawaii- Manoa	Fish
Stefan Andrews	Rolex Scholar	Fish
Abigail Cannon	Scripps Institution of Oceanography	Coral
Will Robbins*	Wildlife Marine	Sharks/Pelagics
Charlie Huveneers	Flinders University	Sharks
Brett Taylor	ARC Centre of Excellence for Coral Reef Studies, James Cook University	Sharks/Parrotfishes
Konrad Hughes	Woods Hole Oceanographic Institute	Coral
Bar Avalon	Independent Contractor	Benthic
Kristin Stohlberg	University of Queensland	Benthic
Kirsty Nash	ARC Centre of Excellence for Coral Reef Studies, James Cook University	Benthic
Valeriya Komyakova		Fish
Shanee Stopnitzky	Living Oceans Foundation Fellow	Benthic
Yogi Freun	FREUND FACTORY - Photography	Photography
Adam Geiger	Sealight Pictures	Videography

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GLOBAL REEF EXPEDITION