BIOT

British Indian Ocean Territory

FIELD REPORT 17

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Khaled bin Sultan
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Front cover: Eagle Island. Photo by Ken Marks.
Back cover: A shallow reef off Salomon Atoll. The reef is carpeted in leather corals and a bleached anemone, Heteractis magnifica, is visible in the fore ground. A school of giant trevally, Caranx ignobilis, pass over the reef. Photo by Phil Renaud.

Executive Summary

Between 7 March 2015 and 3 May 2015, the Khaled bin Sultan Living Oceans Foundation conducted two coral reef research missions as components of our Global Reef Expedition (GRE) program. Our primary objectives were to map and characterize the shallow marine habitats and assess the status of coral reefs and coral reef species within 12 locations in the British Indian Ocean Territory (BIOT).

We undertook the mission in partnership with scientists from NOVA Southeastern University, University of Queensland, James Cook University, University of the Philippines, National Museum of Marine Biology and Aquarium Taiwan, Woods Hole Oceanographic Institute, Scripps University, University of Hawaii-Manoa, the National Oceanic and Atmospheric Agency (NOAA), University of Miami, Our World-Underwater Scholarship Society®, and the Atlantic and Gulf Reef Assessment (AGRRA) program. The research focused on coral reefs and coral communities around 12 submerged banks, atolls and islands from 0-30 m depth.

Scientific Objectives

The main objectives of the research were to map and characterize the shallow marine habitats and to ascertain the current status, health and resilience of BIOT's coral reefs. We acquired WorldView-2 multispectral satellite imagery for each area and conducted extensive bathymetry and drop camera surveys to classify depths and habitat types. This effort included a) an evaluation of the geomorphology and biota of each distinct feature observed on the satellite imagery; b) identification and characterization of different habitat classes and their bathymetry based on this evaluation, followed by possible revision and/or addition of habitat classes to correspond to other classification schemes used in the Pacific; c) mapping of the spatial distribution and extent of each habitat type; and d) mapping of the bathymetry from the shoreline to 25 m depth. Coral reef surveys focused on 3-30 m depth, targeting both fore reef and lagoonal sites. In each location we completed replicate 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), and benthic assessments (10 m point intercept surveys).

We undertook the coral reef assessments to acquire information on: a) the current status of coral reefs in each of eight atolls/islands; b) zonation patterns and population dynamics of coral taxa, reef fishes, algal functional groups, motile invertebrates, and other organisms inhabiting the coral reefs and associated habitats; and c) the health and resilience of these communities. We evaluated the status of commercially important reef fishes and invertebrates, including groupers, sharks, sea cucumbers, mollusks and crustaceans. Specific research focused on stressors associated with climate change and resilience of corals to these stressors.

Applied research focused on 1) the effects of temperature and coral bleaching; 2) changing ocean chemistry and relationship with coral growth rates; 3) coral health; 4) coral disease; and 5) coral predators. We assessed the temperature from the sea surface to the reef and CO_2 concentration and pH of surface waters at each survey location. We collected samples of corals to evaluate coral growth rates and past climate records, symbiont type and concentration, and coral health (through biomarker expression). We also collected tube feet from crown-of-thorns starfish (COTS).

Fig. 1. A coral hind (Cephalopholis miniata) resting under a table acroporid, atop several lobes of Favia.

Research Sites

In total, our science team conducted 1,380 reef fish transects, 1,840 benthic point count surveys, 319 coral belt transect surveys and 2,771 photo-transects from 5-30 m depth on 115 reefs. We also made qualitative observations on five shallow sites (by snorkeling) in Salomon Islands, Three Brothers and Blenheim Reef. We revisited four sites in Peros Banhos at the end of the mission to assess changes to coral communities as a result of a bleaching event that occurred during our second research mission.

We collected a total of 114 cores from *Porites lobata/lutea* to characterize differences in growth rates between islands. We removed 312 samples from 4 species of *Pocillopora* to evaluate variations in symbiont density and type (clade) between islands, reefs, and depths. We also collected 164 *Pocillopora damicornis* and 170 *Seriatopora* spp. samples to assess health and biomarker expression. During the first mission, our partners from Woods Hole Oceanographic Institution collected larger cores from massive *Porites* colonies to assess climate history at BIOT over the past several centuries.

The ground-truthing team collected drop camera videos (1,205), depth soundings (4,459,966) and sediment samples (64) over a total track of 787 km within the 12 locations. They will use these data in conjunction with the satellite imagery to map a total of 3,945 km^2 of shallow marine habitats within BIOT.

Fig. 2. The M/Y Golden Shadow was the research platform for the two BIOT mission

General Findings

Corals

During our reef surveys we observed 51 genera of stony corals, consisting of 45 zooxanthellate and one azooxanthellate scleractinian coral (*Tubastrea*), three hydrozoan corals (*Millepora, Distichopora, Stylaster*), and two octocorals (*Heliopora* and *Tubipora*). While the overall coral diversity was moderately high, reefs tended to be dominated by only a few taxa. Many taxa were rarely seen by us (e.g. *Hydnophora, Euphyllia, Caulastrea, Blastomussa*), and we did not find a few species reported from past scientific missions (*Diploastrea, Trachyphyllia, Plerogyra, Catalaphyllia, Cynarina*).

Acropora and *Porites* were the most abundant corals, followed by *Pocillopora, Leptastrea, Montipora, Favia* and other faviids. Some reefs also had high numbers of *Cyphastrea, Psammocora, Symphyllia, Ctenella, Pavona,* and *Stylophora*. Colonies of *Lobophyllia* were relatively uncommon, except at some lagoonal sites where they could form large stands. *Acropora* and *Porites* were the largest corals overall, and covered most of the substrate. It is interesting to note that we rarely saw the large hemispherical *Porites lutea* colonies on the southern reefs, they were much more abundant in the north, especially on Peros Banhos, Salomon, and Blenheim. In most southern locations, *Porites* colonies formed flattened "pancakes" and larger colonies were extensively bioeroded.

Stands of large table acroporids were restricted to a few reefs in the south (vicinity of Egmont, Danger Island and Three Brothers), occurring mostly in channels and at shallow to intermediate depths (5-15 m) on reefs off emergent islands. Submerged bank reefs within Great Chagos Bank and lagoonal patch reefs in the south appeared to rarely have large stands of these corals. The stands we did find were a mix of live and dead corals. On some reefs, entire stands were dead, in growth position, while others had few dead corals. Table acroporids with white syndrome were found on most reefs. In some locations there were only a few isolated cases while other reefs had a relatively high prevalence (3-5%). In most areas with large stands of dead corals, recovery was apparently underway as indicated by high recruitment found on the substrate. We often found coral recruits, juveniles and small adult colonies on the dead standing table acroporids.

In the north, especially around Peros Banhos, table acroporids were a dominant feature, forming very large stands in the back reef and lagoonal patch reefs from 3-5 m depth to 15-18 m depth. In many places (especially Salomon) we observed a distinct zonation on fore reef locations. The zonation exhibited a mixed coral assemblage (massives, especially faviids, robust branching corals and other species) in very shallow water (1-5 m), dense table acroporids from 5-15 m depth, massive *Porites* colonies from 20-25 m depth, and large overlapping sheets of *Pachyseris* on the deeper reef.

Fig. 3. An unusually large colony of Porites lutea on Peros Banhos. Scale bar is 1 m.

Fish

During the first half of the BIOT Mission, 320 species of reef and reef-associated fish were recorded from 59 survey sites. While the total number of fish species recorded during the mission was relatively less than those observed in locations in the Western Pacific during our Global Reef Expedition (Solomon Islands, Palau, Australia, New Caledonia, and Fiji), the number of species recorded on a transect was still impressive.

In most sites surveyed, large-bodied fish such as groupers (Serrandiae) and snappers (Lutjanidae) were the dominant feature of the fish assemblages. This was an opposite trend than has been observed in many other sites during the Global Reef Expedition, where fish assemblages were dominated by small-bodied families, including damselfish (Pomacentridae) and wrasse (Labridae). In terms of composition, there was less variety and number of damselfishes, wrasses, and butterflyfish (Chaetodontidae) than seen in other Indo-Pacific locations. The majority of the herbivores were represented by surgeonfishes (Acanthuridae) and to a lesser degree by parrotfishes (Scaridae).

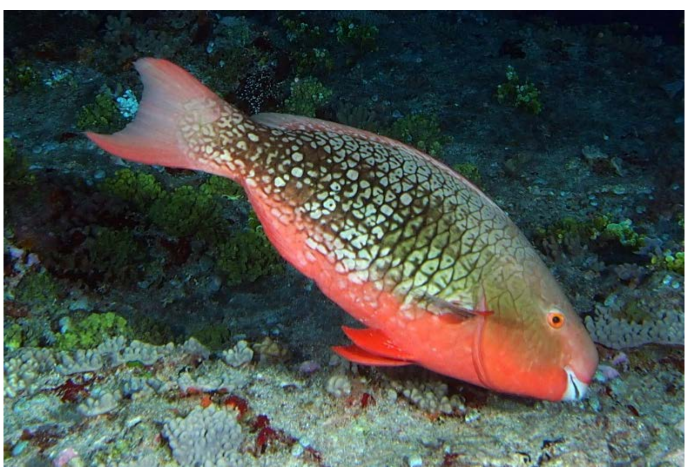


Fig. 4. Large redlip parrotfish (Scarus rubroviolaceus) were commonly recorded during transects in BIOT and made up a large proportion of biomass in many sites.

It is interesting to note the unique behavior of fish towards divers. Most fish (groupers, snappers, surgeonfish, parrotfish, rays and sharks etc.) did not appear to be disturbed by the presence of divers. Often, the fish were curious enough to approach divers. It is very likely that the absence of fishing pressure in the area has not conditioned the fishes of BIOT to be wary of divers.

There was moderate to high fish abundance and biomass in the majority of the sites surveyed. Site BITB27 exhibited a particularly high abundance and biomass of fish. In general, the presence of top predators such as sharks was surprisingly low. The highest abundance and biomass overall was recorded on shallow reefs located off emergent islands. The deeper banks and submerged reefs had lower densities and biomass of fish. It is likely that this was related to the three-dimensional structure of the reef. Submerged reefs and deeper banks often had much lower relief with less live coral, while the most complex coral communities were observed off emergent islands and corresponded with large schools of fish.

Fig. 5. Blacktail reef (Carcharhinus amblyrhynchos) white tip (Triaenodon obsesus) and black tip (Carcharhinus melanopterus) sharks were more common during the first mission, with up to 10 sited on individual dives, although the majority were small in size.

During the second mission, 406 fish species from 50 families were recorded along the 596 belt transects. Wrasse, angelfish and surgeonfish dominated the overall number of species recorded.

Fish abundance and biomass was fairly consistent throughout all survey sites. Big schools of fish (100+) were commonly observed around Salomon Atoll, Victory Bank, Three Brothers and Peros Banhos. Schooling behavior was most notable during the late afternoon surveys, and was particularly evident at the submerged reef in Victory Bank (site BIVB81). Large schools included, but were not limited to, greenthroat parrotfish (*Sarus prasiongathos),* yellowfin goatfish (*Mulloidichthys vanicolensis*), spotted unicornfish (*Naso brevirostris*), barred unicornfish (*Naso thynoides*), black snapper (*Macolor niger*), and humpback snapper (*Lutjanus gibbus*).

Fig. 6. A school of blue-lined snapper (Lutjanus kasmira) on a reef off Egmont Island

Fish assemblage varied with habitat type. Overall diversity was greater on steeper slopes. Lagoonal sites acted as key nursery habitats, with both predatory and herbivorous juveniles represented. In addition, lagoonal habitats supported a high abundance of coral associated damselfish and wrasse. Three species; *Lehtrinus variegatus, Cheilio inermis* and *Coris caudimacula* were only associated with seagrass habitats. Seagrasses also supported unusually high densities of juvenile snappers (e.g., *L. gibbus*). Herbivore abundance was greatest in fringing, submerged and fore reef environments of Salomon Atoll, Victory Bank and Peros Banhos. The highest diversity of butterflyfish were observed in fore reef environments and lagoonal patch reefs the lowest diversity. This may be linked with the level of coral cover and structural complexity.

Fig. 7. Caerulean damselfish (Pomacentrus caeruleus) made up a large proportion of damselfish recorded during transects; often occurring in schools of over 100 individuals.

The abundance, biomass and diversity of groupers (Family Serranidae, Subfamily Epinephelinae) were noticeably high in BIOT and made up a large proportion of fish recorded per transect. Overall, 22 grouper species were recorded with the greatest abundance in fore reef and lagoonal patch reef habitats. Individuals from several species (e.g., *Plectropomus laevis, Epinephelus fuscoguttatus*) were frequently observed up to 90 cm in length. Black saddled coral groupers (*P. laevis*) were the biggest groupers recorded during surveys, with one individual attaining 190 cm in length at Victory Bank. Further to their large body sizes, aggregations between 85-105 black saddled coral groupers were commonly observed in Salomon Atoll, Peros Banhos and Nelson Island. In contrast, rabbitfish (Siganidae) and damselfish (Pomacentridae) were less diverse and comprised a lower proportion of fish recorded per transect.

Six species of sharks were recorded. The tawny nurse shark (*Nebrius ferrugineus*) was the most commonly observed species, with both large pregnant females and juveniles recorded. On separate occasions, two whale sharks (*Rhincodon typus*) were seen cruising in the shallow fringing reef in Peros Banhos. Five ray species (*Manta alfredi*, *Aetobatus narinari*, *Taeniurops meyeni*, *Urogymnus asperrimus* and *Taeniura melanospilos*) were also recorded, most frequently in deeper waters

Fig. 8. A cowtail stingray (Pastinachus sephen) rests in the sand. Large rays like this were frequently seen during transects.

Survey Locations

Cauvin Bank

Cauvin is a drowned submerged bank reef system with a low-relief rim that rises to 18 m depth. Although the navigation chart indicates areas that shoal to 10 m depth, extensive searches did not reveal any shallow habitats. The lagoon has depths ranging from 30-40 m depth with scattered mounds that come up to about 25 m depth. On the imagery these appeared as shallow coral bommies, each 50-150 m diameter, reminiscent of shallow *Porites* and *Acropora* dominated patch reefs seen elsewhere. Upon closer inspection, these mounds were found to be low-relief algal and seagrass dominated that dropped only 3-5 m on their margins. The outer rim has up to 30 cm relief, consisting of patches of dense seagrass, scattered rubble fields with 3-5% live coral consisting mostly of small free-living colonies of *Psammocora*, small faviids and occasional 10-30 cm *Porites, Astreopora, Leptoseris, Pocillopora* and other species. There is 5-10% cover of *Halimeda* in some areas and scoured hard ground in others, rubble patches and sand patches.

Fig. 9. Patches of seagrass observed on Cauvin Bank at 18-20 m depth.

The fish communities were dominated by small-bodied families, including wrasse, angelfish and butterflyfish. The seagrass habitat also performs a key nursery function, supporting many juveniles of larger predatory families, especially snapper (e.g., *Lutjanus gibbus*).

Fig. 10. Benthic substrate at 18 m depth. The hardground was covered with a layer of sediment, small attached and free living corals, crustose coralline algae and Halimeda (below).

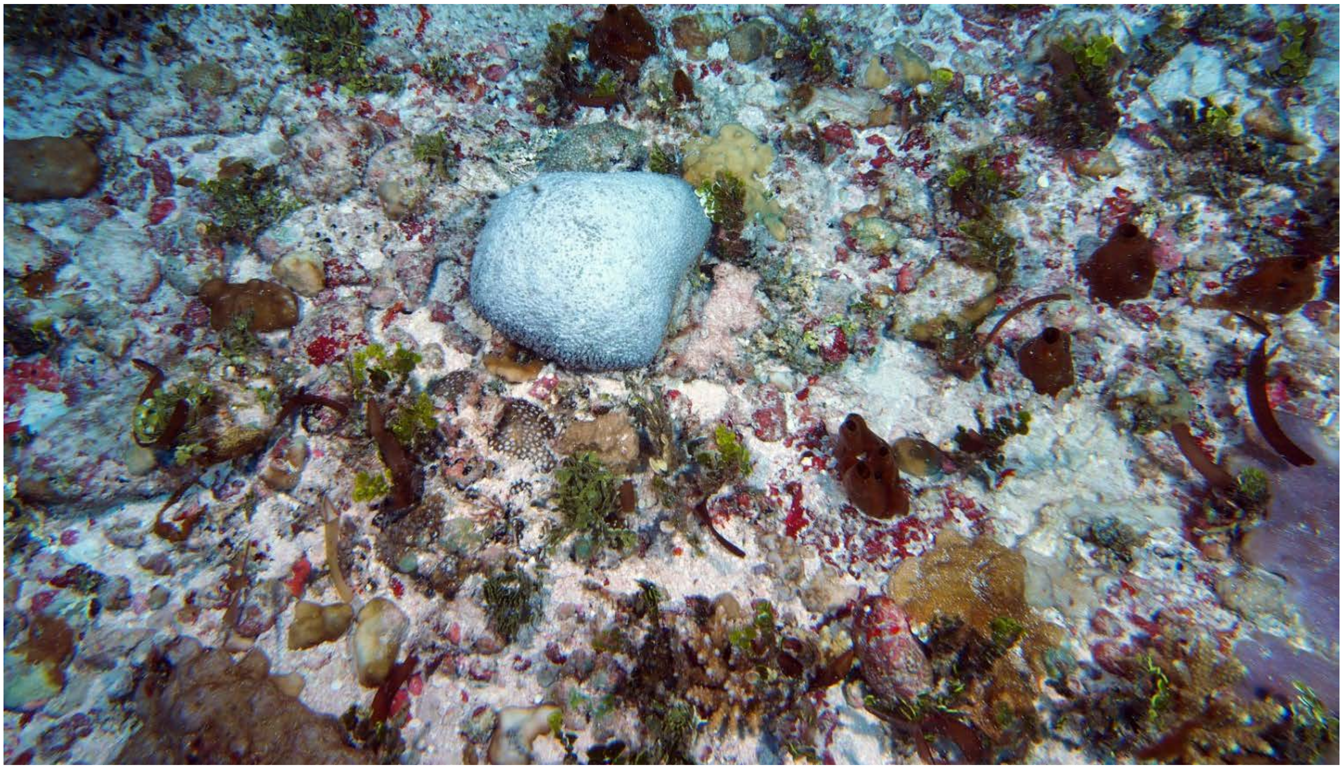


Fig. 11. Typical Acropora-dominated fore reef community off Egmont Island. A school of humpback snapper (Lutjanus gibbus) is present.

Egmont Island

Fore reef communities were represented by a shallow terrace that slopes gradually to 12-15 m, then more steeply (40-60 degrees) to 25-30 m depth. In most areas, highest cover is from 5-15 m, ranging from 20-80%, declining in the shallows and on the deeper reef. Some of the reefs have extensive branching acroporids that form thickets of 10-25 cm tall branches intermixed with thickets of cormybose acroporids that were mostly alive. There were table acroporids on a few fore reef locations, generally to about 15 m depth. These were mostly alive, but there were also dead colonies in growth position, broken tables and about 0.5% with white syndrome. The deeper reef community often has a dominance of pancake-shaped *Porites lutea/lobata* colonies with a mix of acroporids, *Pocillopora*, faviids and other species with 10-30% cover. Relief tends to be 60-80 cm, and slightly higher in areas with table acroporids. There were patches of rubble and overturned corals on the fore reef slope and also on the lagoonal reefs. Some of the windward sites with lower coral cover tended to be low-relief hard ground areas with large gorgonians, patches of leather corals, 20-30% cover turf algae and clumps of *Halimeda*.

There was one very unusual lagoonal reef with mounds of rubble that extended from 3–9 m depth; the rubble is over 1 m deep, unconsolidated and without any live coral. At the base of the rubble slope the bottom alternates from hard ground and sandy areas to coral areas that form 50-200 cm tall mounds, often 5-10 m diameter, dominated by monospecific stands of branching table acroporids, staghorn-bushy acroporids, *Lobophyllia* and mixed communities with faviids, acroporids, *Pavona, Pocillopora, Astreopora* and *Euphyllia*.

Fish communities were dominated by wrasse, surgeonfish, damselfish, butterflyfish, groupers and goatfish. Whitetip (*Trianeodon obesus*) and blacktail (*Carcharhinus amblyrhynchos*) reef sharks, and large bluefin trevally (*Caranx melampygus*) were recorded in deeper parts of the fore reef, in both windward and leeward locations. These fore reef communities were more diverse, supporting up to 21 families whereas less than 10 families were recorded in the lagoonal patch reef (site BIEG07). This shallow site was dominated by algal-farming damselfish and small surgeonfish.

In comparison with other sites surveyed in BIOT, Egmont did not support extremely large schools of fish, with only one or two schools of fusiliers (over 100 individuals) recorded. However, the lagoonal patch reef did support one of the few populations of convict surgeonfish (*Acanthurus triostegus*). This school of over 200 individuals was observed grazing throughout the shallows (<3 m) at this site.

Danger Island

The reefs in the vicinity of Danger Island varied considerably in composition, structure and health. Those located immediately off the west side of the island were dominated by large stands of table acroporids on the slope, to about 15-18 m, and then a progressive transition to large *Porites*, first occurring as a mixed assemblage and later being dominated by pancake growth form and shingles of *Porites* below 20 m, intermixed with very large massive, low-relief faviids. These varied in condition. In some areas a high prevalence of white syndrome was recorded while others had many dead tables, some colonized by recruits and others with few settlers on their skeletons.

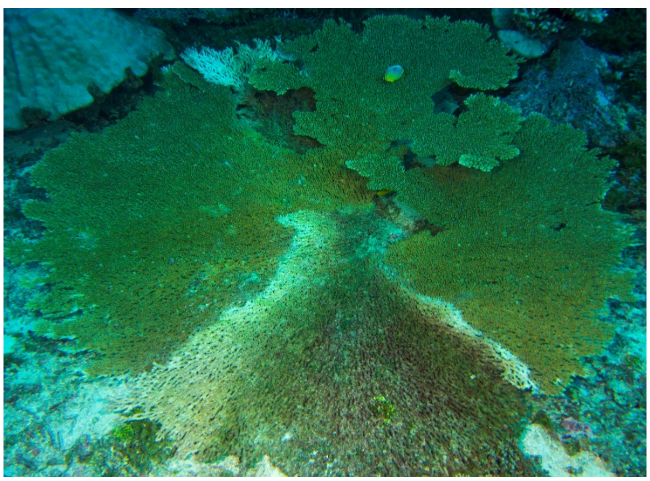


Fig. 12. Prevalence of white syndrome on table acroporids varied considerably with a complete absence of disease in some locations and up to 10-12% prevalence in others. In general, disease was more commonly observed during the first mission.

On the leeward (north east side), the fringing reef had a moderately healthy coral community in shallow water, dominated mostly by small corals, large areas of *Heliopora* and occasional larger corals. From 10-18 m was a very wide (100-200 m) patch of *Acropora* rubble, completely dead, unconsolidated, with no living coral that extended for hundreds of meters. Below this was a transition to a massive community, mostly faviids, with colonies that were 50-150 cm in diameter but only 20-30 cm tall.

The submerged banks away from the island tended to have much less coral. Often the tops of these (10-15 m depth), were hard bottom with very high cover of *Cliona*, and a dominance of small *Pocillopora* colonies, many with partial mortality and disease. The slopes were mostly scoured hardground with 10-20 cm relief and very few large corals. There was a low density of medium sized *Pocillopora, Astreopora, Porites* and faviids, most 20-40 cm along with higher numbers of 1-4 cm diameter corals, including *Pocillopora, Psammocora, Favites, Fungia*, digitate and short branched *Acropora*. Coral cover generally was less than 5%.

On one reef we found extensive patches of seagrass at 23 m and at 12-15 m interspersed with hard bottom areas colonized by small soft corals, erect red and green calcareous algae, and patches of *Cliona*. Vertical surfaces often had high numbers of *Tubastrea*, small branching gorgonians and turf algae.

Fig. 13. Tubastrea was very common in fore reef locations where the slope was steep and there were ledges and caves.

The fringing windward reefs of Danger Island supported some of the largest schools of fish recorded during the mission. Large schools of goatfish, snappers and fusiliers (often with up to 500 individuals) were seen regularly in these sites.

Overall fish diversity was high, with over 30 families identified during surveys. Fish assemblage was again dominated by damselfish, fusiliers, surgeonfish and goatfish. In addition to these families many predatory families, such as groupers, emperors and snappers, comprised a large proportion of biomass recorded during transects. Large black-saddled groupers (*Plectropomus laevis*) over 100 cm in length were recorded in site BIDI10, a fringing leeward reef, whereas individuals on the windward site tended to be slightly smaller in size.

Eagle Island

Many of the reefs adjacent to the island had a shallow gently sloping fore reef community that extends seaward between 50-100 m to depths of 10-15 m. This terrace had dense population of table acroporids, completely dead on some reefs and alive on others, intermixed with mostly live *Porites lutea/lobata*. The *Porites* colonies included the typical hemispherical colonies 1-1.5 m diameter/height, with higher numbers of smaller, flattened pancake-shaped massive colonies. There were also numerous *Pocillopora* and *Stylophora* colonies, most 20-60 cm with up to 30-40% exhibiting signs of recent mortality from disease.

Often, at the edge of the terrace and the top portion of the reef slope (12-15 m depth) was a rich coral community with places that had 60-80% cover consisting of *Stylophora, Galaxea, Symphyllia, Favites, Porites, Favia stelligera*, small *Acropora, Platygyra*, and *Gardineroseris* and 5-10% cover of leather corals.

The reef then slopes steeply (sometimes nearly vertical) with numerous undercut ledges and cave systems. Much of the slope has few stony corals while the best coral communities were found at the base of the ledges, on near horizontal areas, and around the perimeter of the caves. Dominant taxa include *Platygyra, Astreopora, Symphyllia, Favia, Favites,* small branching tables and bushes of *Acropora* along with crusts of *Montipora, Leptastrea*, and *Pavona*. Large gorgonian sea fans, black coral, branching *Tubastrea micrantha* were common constituents of the deeper reef slope, with orange tube coral *Tubastrea* dominating on the undersides of ledges.

The submerged bank reefs were similar to those seen around Danger Island. The shallow reef top (10-14 m) was typically relatively flat, low relief with up to 60% cover of *Cliona* intermixed with patches of small *Pocillopora, Acropora*, faviids, *Porites* and other species. Cover of corals was generally no more that 5-10%. Cliona disappeared on the reef slope and coral cover increased, with some areas having 30-40% cover. The community was dominated by medium-sized *Porites, Platygyra, Ctenella*, small to medium *Pocillopora* (5-40 cm), *Stylophora* and numerous other species. The slope often had patches of *Halimeda* and areas covered with leather corals.

Fig. 14. Cliona covered much of the substrate on the tops of submerged bank reefs between 10-14 m depth, and could often be seen overgrowing and bioeroding massive corals.

A few unusual deeper areas were examined including BI22. This region has extensive reef habitat with large sand channels separating reef communities. Areas with coral have high (up to 100 cm) relief and numerous large massive corals, often 1-2 m diameter including *Porites*, hemispherical *Goniastrea, Symphyllia, Favites*, and *Pavona* along with large (50-60 cm) *Pocillopora, Pachyseris* and other species. Coral cover was approximately 30% with 20-30% *Sarcophyton*, 2-5% gorgonians, and 5-10% cover of *Halimeda*.

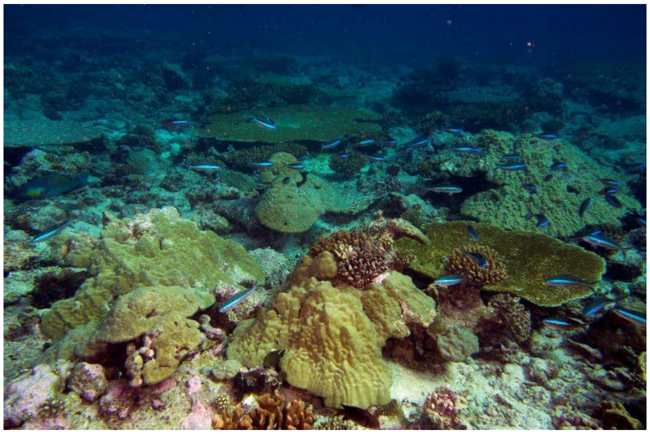


Fig. 15. The reef community at EA27 (25 m depth) consisted predominantly of medium-sized Porites colonies intermixed with small (up to 1 m) table acroporids, Pocillopora and other corals.

In some locations the reef slope had a very high cover of *Halimeda*, while this algae was virtually absent from others. There were also areas with very high cover of *Sinularia/Sarcophyton* leather corals, encrusting sponges and tunicates, especially on submerged bank reefs within Great Chagos Bank.

Three Brothers

The surveys included leeward and windward fringing reef communities off the three islands and Redemption Rock as well as submerged bank reefs along the margin of Great Chagos Bank and submerged patch and bank reefs within the Bank.

The best developed coral communities were found adjacent to the islands, and in particular the channel reefs between the islands. These often had a narrow reef flat community that was 2-5 m deep, sloping gently to 5-10 m, with a slightly steeper fore reef slope with coral extending to 25-30 m depth. Shallow communities were often dominated by small faviids, robust digitate and cormybose acroporids, *Pocillopora*, *Stylophora*, and other species. Live coral cover occasionally approached 80%.

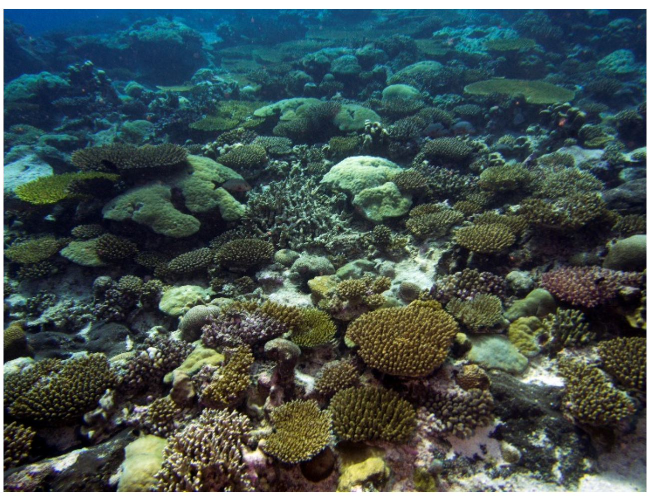


Fig. 16. Shallow fore reef communities often had high numbers of robust, stout branched acroporids and low-relief massive Porites colonies.

From 5-20 m depth many of these reefs had prominent table acroporids communities, but these ranged from mostly live (these were predominantly in the channels) to mostly dead. On several reefs nearly all the acroporids had died but we recorded extensive recruitment and skeletons were covered in recruits, juveniles and small adult colonies. Massive *Porites* also dominated on the fore reef slope, especially below 15 m depth. Some of these formed mounding colonies but most were large (50-500 cm diameter), flattened thick bladed colonies and overlapping shingles. Interspersed among these were very large faviids, *Symphyllia*, massive *Pavona* and other species.

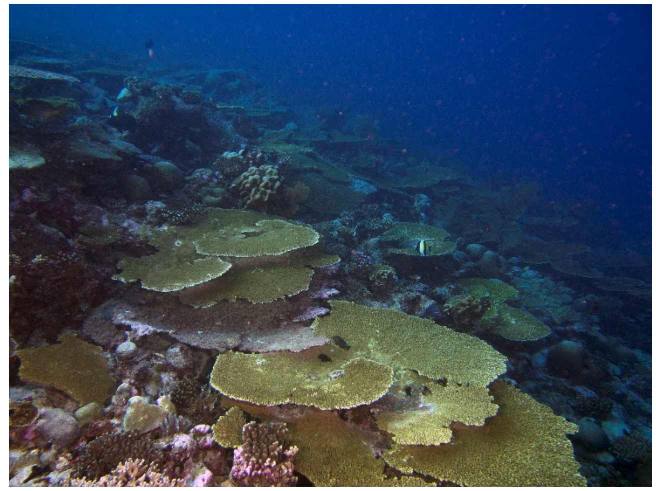


Fig. 17. The reef slope adjacent to channels often had high cover of table acroporids.

Several of the deeper reef communities off the islands, especially near channels, had extensive monospecific stands of foliose *Echinopora*. BITB38 and BITB57 were exceptional in having the highest coral diversity in the region, very high cover and distinct zonation with a wide band of living table acroporids, huge *Favia* and *Gardineroseris* colonies. Extensive fields of foliose *Echinopora*, and *Pachyseris* on deeper reefs. These reefs also had large schools of snapper, jacks, several large giant grouper and many other grouper, huge bait balls and numerous sharks.

Some of the fore reef communities on the windward sides had very steep slopes with low coral cover and high numbers of large gorgonian sea fans, black coral, and *Tubastrea micrantha* colonies, with patches of leather corals, turf algae, encrusting sponges and other invertebrates.

Submerged bank reefs generally came up to 12-15 m depth with a shallow terrace and a gradual slope to 25-30 m. The shallow terrace often had a moderate abundance of staghorn tables intermixed with lower numbers of pancake *Porites*, *Pocillopora*, occasional faviids, *Hydnophora*, *Gardineroseris*, *Turbinaria*, *Galaxea*, *Platygyra*, and a few other taxa. Cover was usually 5-15% although some reefs had up to 30% and relief was generally never greater than 40 cm.

A small proportion of the staghorn acroporids were dead on each reef and up to 10% had signs of white syndrome. White syndrome was also common on *Pocillopora* and *Stylophora*. The slope tended to have less coral (usually no more than 10% cover), 30-40 cm relief, along with a high cover of *Halimeda*, patches of coral rubble and occasional patches of leather corals, turf algae and crustose coralline algae. On some reefs, there were sheets of *Echinopora, Pachyseris* and *Turbinaria,* higher numbers of "pancake" *Porites*, and patches of *Seriatopora* near the base of the slope, but extensive stands of these corals were uncommon.

Fish communities in Three Brothers were diverse and abundant, with many reefs supporting a huge biomass of reef and reef-associated fish. Predator biomass was particularly notable in this location, with reef sharks (up to 1.3m) recorded during most dives, and transects dominated by snappers and groupers. Red snapper (*Lutjanus bohar*) were especially abundant on bank reefs, often attaining maximum size.

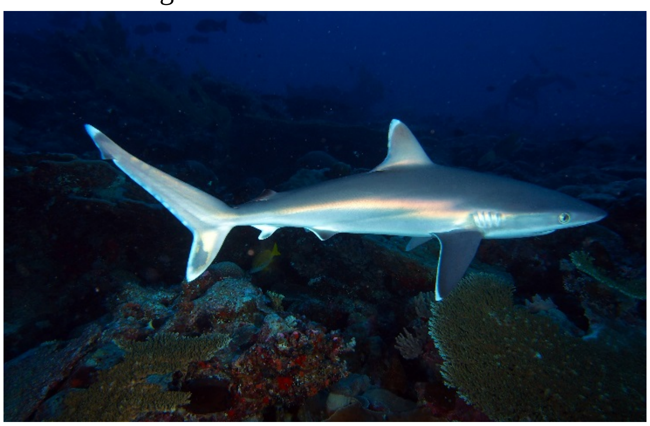


Fig. 18. Most of the reefs located on the windward sides near the islands supported large populations of reef sharks.

Large pelagic predators such as great barracuda (*Sphyraena barracuda*) and small-tooth jobfish (*Aphareus furca*) were also frequently observed in deeper waters of many sites surveyed. Courtship behavior of several large grouper species was observed during surveys.

Herbivore and planktivore densities were also high, with schools of 400 to 600+ fusiliers recorded in deep waters in sites BITB 46, 57 and 29. Parrotfish biomass and abundance was fairly consistent throughout Three Brothers, although both abundance and biomass were larger in South Brother.

Peros Banhos

Fore reef communities varied considerably depending on exposure, slope and location relative to islands. Some reefs had a very gentle slope with mostly hardground, small spurs and small massive and robust branching corals in the shallows, moderately high cover dominated by table acroporids at intermediate depths (5-15 m), and a mix of table acroporids and large *Porites lutea*, large faviids and other species on the slope from 15-25 m.

Some fore reef communities with a wide, gently sloping terrace in shallow water were dominated by medium-sized (1-2 m diameter/height) hemispherical *Porites* colonies and occasional patches of lobate *Pavona*, with table acroporids at the outer edge of the terrace, adjacent to the slope. Coral cover on these reefs quickly dropped off below 15 m depth.

On windward fore reefs with a steeper slope, these were often scoured hardgrounds or turf dominated hardgrounds, with sand patches, lower coral cover, and more turf algae, leather corals and gorgonians, and patches of *Cliona*. Corals on these exposed reefs were very low relief, and often formed crusts or submassive colonies, especially *Pavona, Montipora, Leptastrea,* other faviids and *Astreopora*.

Submerged patch reefs within the lagoon had well developed coral communities with high cover, diverse species assemblages and low prevalence of disease. Most lagoonal reefs had a large, relatively flat terrace at 5-10 m depth dominated by coalescing and overlapping table acroporids, some elongate thickets of staghorn coral and occasional very large *Porites lutea* bommies, some 4-5 m diameter and 2-3 m tall. Cover was 60-90% with most table acroporids over 1 m, up to 3 m diameter.

The table acroporids extended down the slope to 15-20 m depth. At the base of these stands the slope was much more gradual and the community changed to one dominated by patches of *Lobophyllia*, cormybose and staghorn-type acroporids, faviids, *Symphyllia*, mounding and plating *Pavona*, *Gardineroseris*, patches of free-living fungiids, stands of *Goniopora, Turbinaria*, small thickets of *Seriatopora*, and occasional *Hydnophora, Euphyllia*, *Caulastrea* and *Physogyra*, along with other taxa. The corals were interspersed with sand patches and hardground. Beginning at about 20 m, foliaceous *Echinopora* colonies began to dominate. Extensive stands of *Echinopora, Goniastrea, Favia* and other low-relief encrusting and submassive corals extended into the lagoon often to 40-45 m depth.

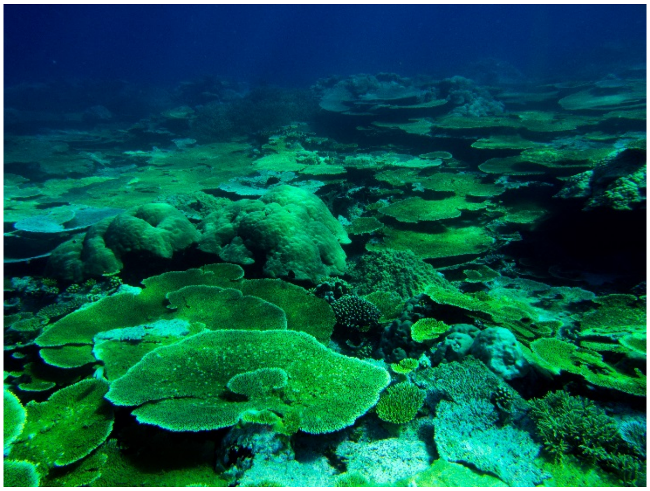


Fig. 19. Lagoonal patch reefs often had large Potites lutea colonies intermixed with table acroporids on the top of the reef (top), a slope with some areas dominated by table acroporids and others with large thickets of staghorn acroporids (middle) and a deeper reef community dominated by foliaceous Echinopora colonies (bottom).

Fish communities in the fringing reefs of Peros Banhos were dominated by small-bodied planktivorous and piscivorous families, predominantly anthias, sweepers and small triggerfish. Remarkably, two whale sharks were observed on separate occasions in the shallow waters of windward fringing reefs (BIPB 69 and 112). Manta rays were also seen regularly in Peros Banhos. This assemblage suggests good water movement and a highly productive environment.

Speakers

The fore reef community at the southern end of the bank is mostly a scoured hardground in shallow water (8-12 m), with a well-developed coral community on the slope from 12-25 m depth. Throughout the mid depths, small to medium (20-80 cm) massive, plating and branching corals occurring in 1-2 m patches between larger thickets of table acroporids. Dominant species are *Porites, Leptastrea, Goniastrea, Pachyseris, Pavona varians, Pocillopora Stylophora, Acanthastrea, Platygyra, Symphyllia* and *Montipora*. Table acroporids increase in abundance from 15-20 m with 40-60% live cover and 40-80 cm relief. About 5% of these corals are dead, but disease was very rare and bleaching was much less than that observed on other reefs. The table acroporids had a prominent understory community as well as numerous large massive corals, plating corals and robust branched corals between the tables including *Porites, Platygyra, Favia*, and *Turbinaria*, with most colonies from 60-100 cm diameter. Live coral cover from 15-25 m was up to 60%, with about 20% dead corals colonized by turf algae.

The rim surrounding the bank was typically from 8-14 m depth, with minimal coral in the shallows, mainly scattered table acroporids, small massive and submassive corals, *Pocillopora* and *Stylophora*, and a higher number of staghorn tables. Coral cover was generally <5% cover, with up to 60% cover of rubble, and elongate narrow (50-100 cm wide) sand patches that run perpendicular to the rim. On the slope, there gradually becomes more table acroporids, with 30-60 cm relief and small massive and branching corals as understory corals.

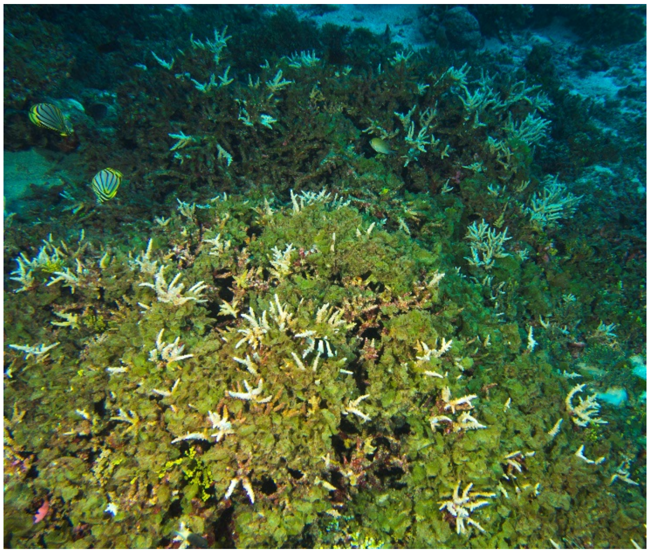


Fig. 20. Very high cover of Microdictyon was often seen on deeper reefs, especially among the branches of acroporids.

Back reef communities and lagoonal patch reefs ranged from low relief hard ground areas with sand patches and extensive sea grass meadows to areas dominated by a mix of table acroporids, large massive corals including *Porites*, *Favia*, *Symphyllia* and *Pavona*, thickets of branching Acroporids and small faviids, *Astreopora*, *Montipora*, *Echinopora*, *Stylophora*, and other species. This was one of the few areas where branching *Porites* colonies were a major constituent of the community. Seagrass communities were most prevalent in the north and northeastern end of the bank.

Fig. 21. On several reefs, seagrass beds were interspersed with coral dominated habitats, rubble fields and sand flats.

The lagoonal patch reefs at Speakers Bank supported high densities of damselfish, wrasse and surgeonfish. Predatory biomass and abundance was lower in Speaker's compared with other islands surveyed.

Victory Bank

Victory Bank was characterized by a submerged reef system that formed a shallow rim around the perimeter that was rarely less than 12 m depth. The top of this rim was mostly a scoured hardground, with some sand patches, rubble fields, and areas colonized by staghorn table acroporids, *Millepora* dominated stands, small robust branching corals, small *Porites* and Faviids (generally less than 10% cover). Slightly deeper (12-15 m), low relief hardground areas were interspersed with dense coral communities, up to 1 m relief consisting of areas with 2-3 m diameter mounds of *Pocillopora*, 1-2 m diameter patches of *Heliopora*, and mixed robust branching coral communities with up to 30% coral cover, 30% crustose coralline algae (CCA) and 40% turf algae. Table acroporids appear at 15-18 m depth and are the dominant coral to 25 m depth, with 30-40% cover forming colonies 40- 60 cm tall. Below this was an extensive deeper reef community with 3-5 m coral bommies colonized by a mix of large table acroporids, *Porites lutea* and faviids, patches of branching acroporids, and small stands of *Echinopora, Turbinaria, Pavona*, plates of *Montipora, Astreopora* and other species intermixed with numerous gorgonians and sponges.

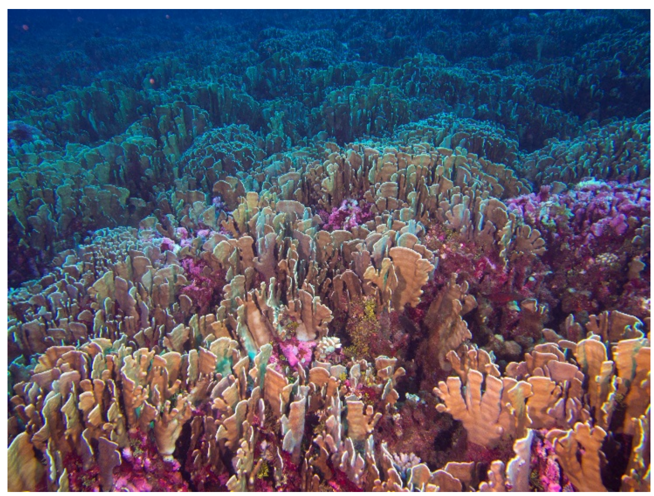


Fig. 22. Site VI109 had extensive stands of blade-like Millepora.

One site within the bank, located next to a channel (VI109) was particularly notable. The shallow reef top at 10-12 m was colonized by a dense stand of *Millepora* that extended in all directions for 100s of meters. Within the stand most of the coral was alive, with 60-80% live cover, while some areas at the perimeter were completely dead in growth position. The perimeter of this stand, adjacent to a sand channel was completely bleached white while inner corals were pale. Between the *Millepora* stand and the sand channel, running down the slope from 10-25 m depth, the reef was dominated by high cover of massive, encrusting and branching corals, including 30-100 cm *Porites*, cormybose acroporids, a few table acroporids, *Pocillopora*, faviids and other corals; most of the corals were completely bleached. From 18-30 m depth there was a steeper slope with a *Porites lutea* dominated area to 25 m depth and a mixed coral zone consisting mostly of *Porites*, *Pachyseris*, *Platygyra*, *Leptastrea*, and *Favia* that continued to 35 m depth. Coral cover was up to 60%, with 60-120 cm relief.

Fish biomass and abundance was very high in Victory Bank. Schooling behavior was evident during most surveys, especially in the submerged reef, with schools of snappers and fusiliers often exceeding 500 individuals. The largest *Plectropomus laevis* individuals were recorded in Victory Bank, often attaining 190 cm in length.

Diversity, abundance and biomass were greatly reduced in the lagoonal patch reef; with this environment predominantly supporting surgeonfish and small wrasse species.

Blenheim

Shallow fore reef communities above 8 m were largely represented by a scoured hardground with some scattered acroporids, *Stylophora*, *Pocillopora* and encrusting and submassive faviids, *Montipora*, and *Porites*. At 10 m there are more medium-sized (up to 80 cm) massive corals such as *Pavona*, *Favia stelligera* and *Platygyra* and high numbers of 10-20 cm corals, especially *Stylophora*, *Pocillopora*, digitate acroporids, *Gardineroseris* and other species. The reef slope is dominated by 10-25 cm *Stylophora* intermixed with digitate and short-branched *Acropora* tables, *Pocillopora* and small massive and submassive corals, along with a few larger massive faviids, *Pavona*, *Gardineroseris*, *Symphyllia* and other species.

Between 15-24 m, some fore reef communities have very large patches of branching *Millepora* running down the slope. In places these are growing up and around foliaceous *Echinopora* colonies. Other reefs have communities dominated by foliaceous *Echinopora*, massive *Platygyra*, *Favia*, *Goniastrea* and other faviids, *Gardineroseris*, stout branched *Stylophora*, and *Pocillopora*, stands of branching *Porites*, some medium-sized *Porites lutea*, encrusting *P. varians*, *Astreopora* and *Montipora*.

There are many more plating corals below 25 m, especially *Mycedium*, *Pachyseris*, and *Merulina*. In some areas the deep reef also has very large (50-100 cm) faviids especially *Goniastrea*, *Favia*, *Favites*, along with *Symphyllia* and *Porites* colonies, most of which are flattened (10-20 cm in height).

Live coral cover on the fore reef ranged from 5-10% in the shallows, increasing to 30- 40% at mid depths, with up to 30% CCA and 10% *Halimeda*. Several reefs also had high cover (30-40%) of leather corals.

Blenheim is completely enclosed, with very few passages into the lagoon, except in one location in the south. The lagoon is relatively shallow (generally no more than 15 m deep), with a reticulated system of patch reefs. The patch reefs have extensive ridges and mounds that are 1-2 m tall and a few bommies up to 3 m tall, separated by sand patches and channels. These reefs are emergent in places, but most have a shallow (1-2 m) terrace covered in nearly 100% in live *Acropora florida*. These corals were completely bleached white, with some colonies starting to die (3%) and covered in fine turf algae.

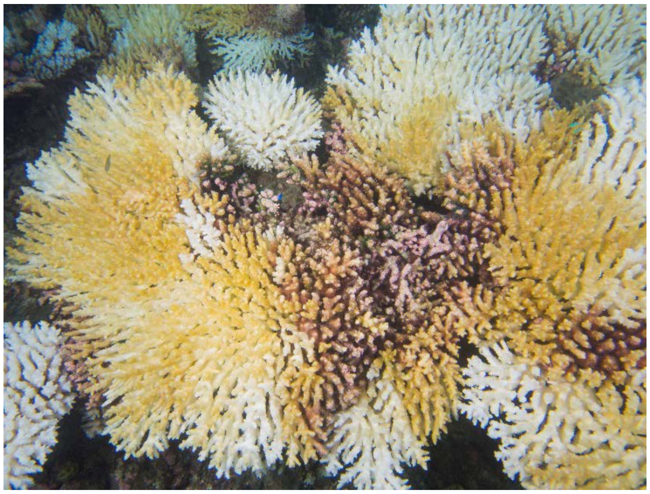


Fig. 23. On some reefs the bleached acroporids colonies had started to die and were colonized by diatoms and fine filamentous algae.

A. florida runs down the sides of the pinnacle, being dominant to 5-6 m. Below this, there is an increase in *Lobophyllia*, *Montipora*, *Stylophora*, *Porites cylindrica* and *Goniastrea*. From 8-15 m depth, there are numerous 1-2 m diameter/height *Porites cylindrica*, some tall *A. florida*, and occasional *Porites lichen* mounds. Goniastrea is the dominant coral covering 30% of the bottom in 5 m depth and decreasing to 5-10% in 15 m. Turf algae and dead coral skeletons increase with depth, and there are high numbers of jewel damselfish algal lawns.

The fore reef sites in Blenheim were one of the few locations that humphead wrasse (*Cheilinus undulatus*) were recorded. Other large species, such as great barracuda, trevally, and several snapper species also contributed towards Blenheim's fish biomass.

Blenheim's lagoonal patch reef supported a surprisingly high biomass and abundance of reef fish, with parrotfish, trevally and snappers recorded in addition to the usual assemblage of small damselfish and wrasse.

Nelson's Island

Patch reefs located within the bank sloped very gradually from 8-12 m depth to a sand flat around 23 m, with a second reef system at 25-28 m. The shallows are low relief (30 cm) with some hardground areas, small to medium massive and branching corals and up to 10% cover table acroporids (most bleached), most 80-150 cm diameter, and scattered larger *Porites* along with small to medium massive taxa (especially faviids). Relief increases to 100-300 cm on the slope due to the presence of very large *Porites lutea* (up to 5 m diameter), table acroporids, and a mixed coral assemblage of 10-80 cm *Favia stelligera*, *Pocillopora*, *Platygyra*, *Goniastrea*, and other species. Coral cover ranges from 30-50% at 15 m, up to 60-80% at 20 m. The second reef system (25 m depth) has lower relief (60-80 cm), more foliaceous *Echinopora* colonies, along with numerous massive faviids, *Pocillopora* (20% with disease), small to medium table acroporids and medium sized *Porites* colonies, along with high number of *Platygra* and *Stylophora* and a few *Seriatopora* and *Symphyllia* colonies. Leather coral was uncommon in deeper water, with up to 20% cover at 10-12 m depth. *Halimeda* occurred in small patches with no more than 5% cover.

Back reef areas and patch reefs closer to Nelson's Island and on the surrounding bank system appear to have been disturbed by a past COTS outbreak. There were a few live table acroporids and very large bleached *Porites lutea*, scattered patches of *Turbinaria* and low densities of small Porites (10-20 cm), *Pocillopora* (10-30 cm) and *Stylophora*. Most of the rest of the reef system was dead from shallow water to 25 m. Dead table acroporids (1-2 m diameter), and medium-sized (20-50 cm) dead colonies of *Porites*, *Pocillopora* and *Stylophora*, all in growth position, cover 60-80% of the bottom. There are also several small massive and submassive faviids, and a few live *Pocillopora, Stylophora, Pavona varians* and *Montipora* crusts. Coral recruitment was particularly low. *Sarcophyton* formed large patches (3-4 m), covering up to 20% of the substrate, with up to 10% cover of Halimeda, 80% turf algae, and 10% CCA.

One lagoonal reef at the western end of Great Chagos Bank (NI80) had a shallow (8-12 m) terrace with mostly small to medium digitate acroporids, *Pocillopora*, *Stylophora*, along with small staghorn and cormybose table acroproids and some larger table acroporids. On the slope, from 12-20 m the community was dominated by table acroporids, with some small to medium *Porites* and other faviids, *Pocillopora*, *Acroporids*, *Echinopora* between the *Acropora* patches. These were about 10% dead, 10% with white syndrome and 30% with recent COTS predation. We identified an active outbreak of COTS (counted 194 COTS within a 10 X 50 m area) with dozens of starfish concentrated primarily around the large table acroporids.

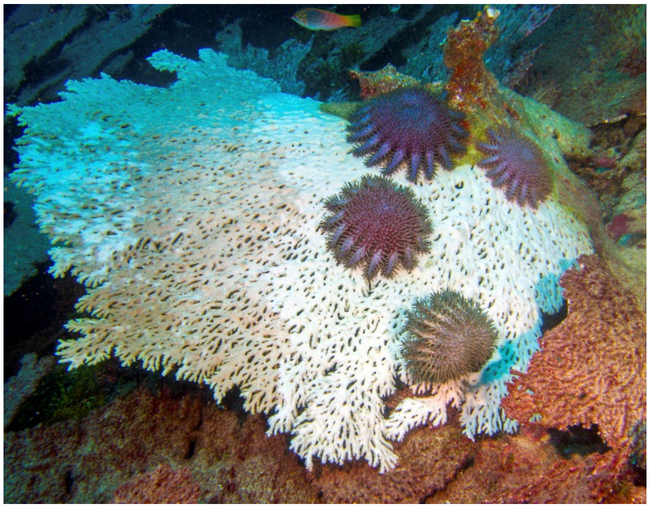


Fig. 24. An outbreak of crown-of-thorns starfish was found on one bank reef near Nelson's Island. Seen here, the COTS are decimating a bleached table acroporid

Reef fish biomass and abundance appeared to be lower in Nelson Island compared with other locations surveyed. School size was lower in these reefs, although there were still good populations and diversity of predatory species, including tuna.

Salomon Atoll

Reef systems around Salomon had the most diverse coral communities observed at BIOT. Most fore reef systems on the northern side had very high cover and distinct zonation patterns. The shallow fore reef was dominated by a host of species such as robust branching *Acropora*, *Stylophora*, *Pocillopora*, small massive, submassive and encrusting faviids, small to medium massive *Porites*, *Pavona*, *Gardineroseris*, *Ctenella*, *Symphyllia*, encrusting and plating *Montipora*, *Echinopora*, *Astreopora* and other taxa, with live coral cover ranging from 30-80%.

Beginning around 5 m and extending to 15-20 m, the community was dominated by table acroporids. These were mostly live on some reefs, while some areas had a mix of live and dead colonies. Below this was a distinctive massive community with very large *Porites* colonies interspersed among table acroporids. Several deeper reef areas had large stands of foliaceous *Echinopora*, and then a prominent deeper community with very high cover and unusually large sheets of *Pachyseris*.

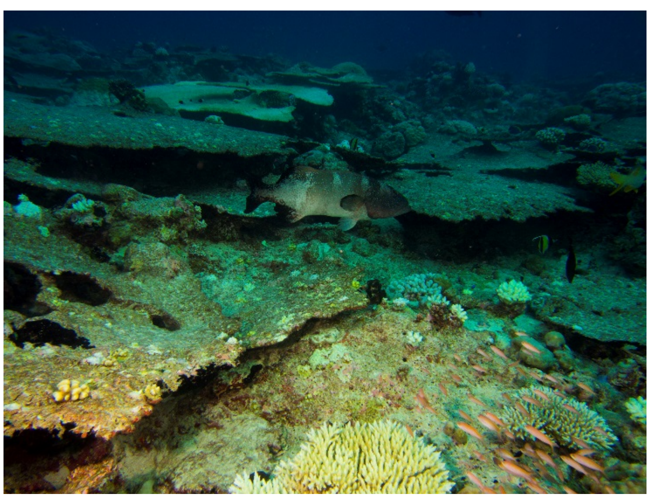


Fig. 25. There were several fore reef locations where most of the table acroporids were dead.

Several fore reef areas had a double reef system, with the table acroporid community extending to 18-20 m, and a wide sand flat with scattered massive corals separating these from the second reef system. The second reef system had areas dominated by table acroporids, along with branching *Acropora* thickets, cormybose acroporids, *Porites*, large faviids and numerous species of encrusting and plating corals on the deeper fore reef slope.

Fig. 26. On fore reef locations, extensive bleaching was observed among many of the stony coral taxa as well as anemones, as shown here.

The fore reef communities on the eastern side often had a wide shallow (3-12 m) gently sloping terrace, with a dominance of medium to large hemispherical *Porites lutea* and *Pavona clavus* colonies, a band of table acroporids at the edge of the slope, and a well-developed, high-relief, mixed coral community with many large *Porites* colonies at the top of the slope, and then a steep slope with ledges, undercut areas and small caves. The deeper reef had much lower coral cover and more gorgonians.

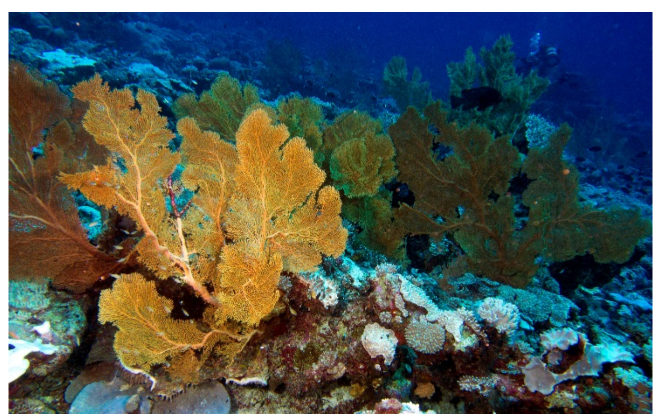


Fig. 27. Deeper reef communities off the east side of Salomon had lower coral and more gorgonian sea fans.

Lagoonal patch reefs varied considerably throughout the atoll. The reefs generally had a relatively flat terrace at 3-8 m depth with large *Porites* colonies, but some reefs that were only 1-2 m below the water's surface had more of a branching coral community with smaller massive species, especially *Favia stelligera*, *Platygyra*, *Pavona*, small *Porites*, as well as some large colonies of *Galaxea*, *Lobophyllia* and numerous other faviid species. On the slope, there were areas with unusually large *Porites rus* colonies, mounds of *Lobophyllia*, Sheets of *Porites lichen*, large *Goniopora* colonies, areas dominated by *Porites cylindrica* and other branching *Porites*, patches of *Seriatopora* and many other species.

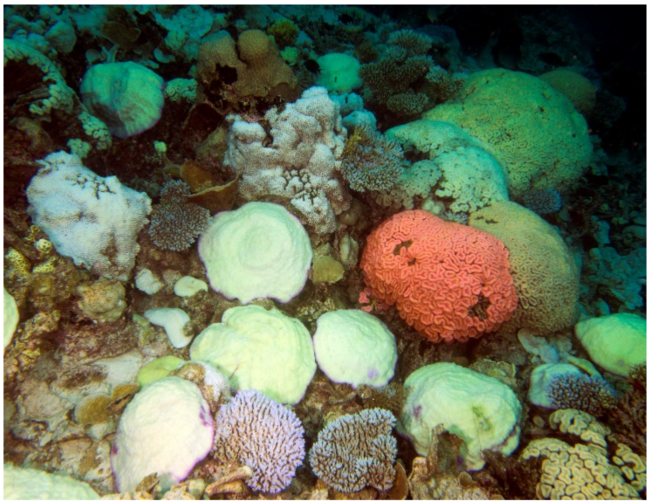


Fig. 28. Lagoonal patch reefs were diverse, but many of the corals were bleached.

At the base of the slope within the lagoon, the reef framework was mostly constructed of columnar and mounding *Porites* colonies. Many of these were largely dead, with live tissue only on the upper surface.

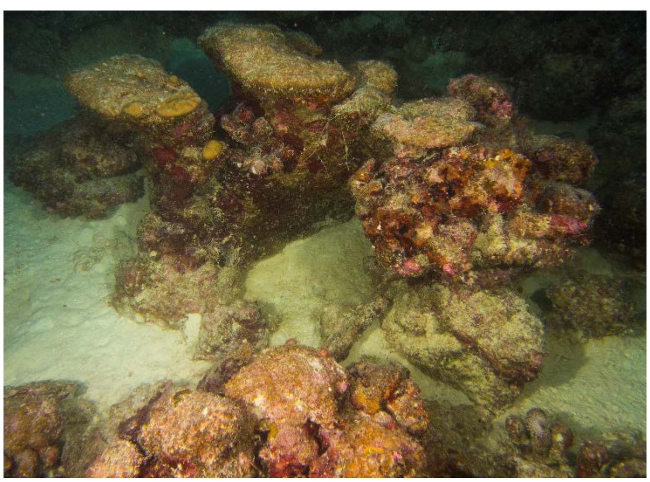


Fig. 29. A Porites framework was a common feature of lagoonal patch reefs.

Relief in the deeper area ranged from 50-200 cm; most corals were 1-2 m diameter and height with patches of fine sediment between the corals. In areas with branching acroporids and other branching species, there was often high cover of *Microdictyon* and *Halimeda* and some areas with cyanobacteria.

Biomass and abundance of reef fish was particularly high in Salomon. Large schools and aggregations of predatory (e.g., *Plectropomus laevis)* and herbivorous (e.g., *Chlorurus sordidus*) families were recorded during most surveys.

Fig. 30. Schools of paddleback snapper

The fore reef environments supported enormous schools of anthias and chromis, with many containing over 1,000 individuals. The channel patch reef (Site BISA 97) supported a large biomass and abundance of parrotfish and surgeonfish, and only small numbers of predatory families were recorded.

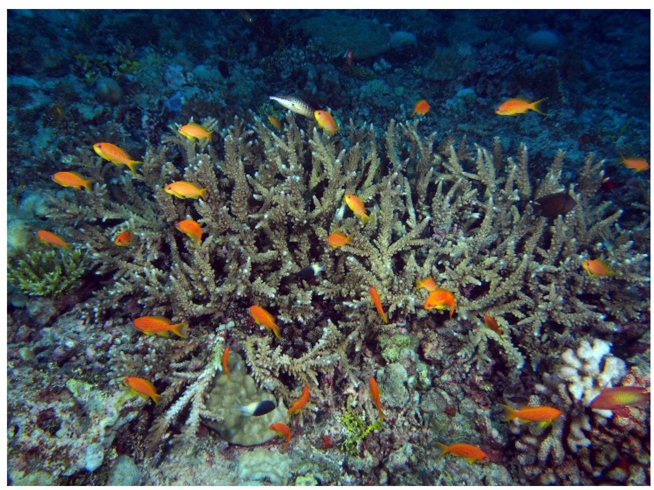


Fig. 31. A small school of Anthias among a branching Acropora colony.

An oceanic sunfish *(Mola mola)* was recorded at 26 m depth in Site BISA 105. This was the only individual observed during the mission in BIOT.

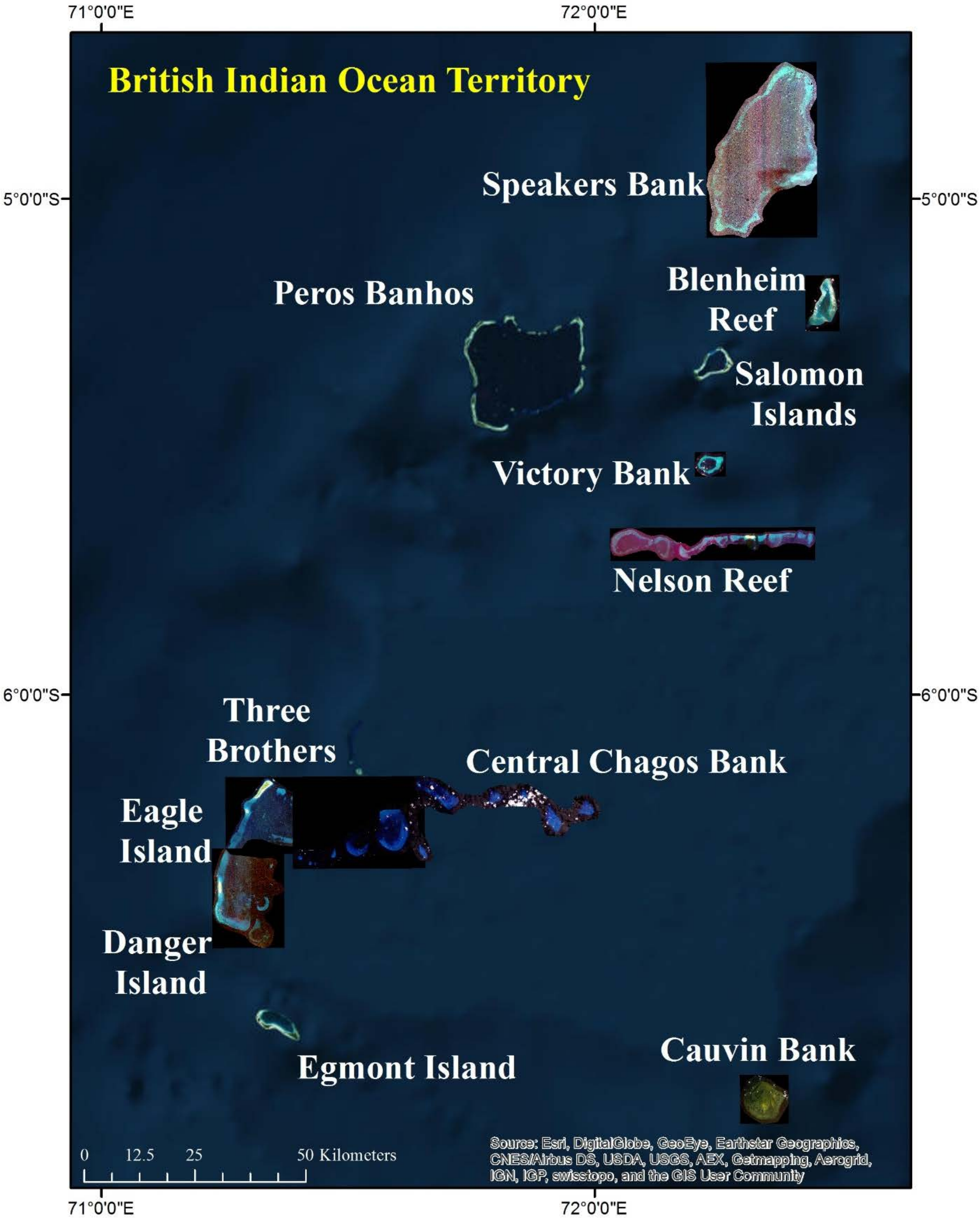


Fig. 32. Map of the British Indian Ocean Territory showing the 12 areas where we worked.

Methods

Coral reef surveys, research and habitat mapping was conducted in five regions of the British Indian Ocean Territory (Fig. 31), with work focused on reefs in the vicinity of Cauvin Bank, Egmont Island, Great Chagos Bank (Eagle Island, Danger Island, Three Brothers, Nelson Island), Blenheim Reef, Speakers Bank, Salomon Islands, Peros Banhos, and Victory Bank.

Habitat Mapping and Groundtruthing

Using multispectral satellite imagery obtained from DigitalGlobe WorldView-2 satellite, high resolution bathymetric maps and habitat maps will be created for shallow marine environments from 0-25 m depth. Groundtruthing efforts necessary to develop these maps focus on continuous bathymetry measures, drop camera analysis, sediment characteristics and characterization of habitat features using acoustic sub-bottom profiling equipment(Stratabox and Hydrobox) and fine scale photo-transect surveys.

A. Satellite imagery

A total of 3,945 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 navigation 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 currently being used in conjunction with ground truth data to create bathymetric and benthic habitat maps.

B. 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 deployed from the survey boat and flown close to the sea floor as it recorded video for 15 to 60 seconds. During this time, the laptop operator watched the video in real-time and guided the drop-cam operator to raise or lower the camera to prevent contact with the substrate.

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 thelimited length of the tether cable (50 m). The acquired videos will be used to create the benthic habitat maps by providing the necessary information for developing the habitat classification scheme and training of models used to classify the spatial extent of different habitat types.

Fig. 33. Deploying the Stratabox at Peros Banhos to identify potential Pleistocene reef structures below the lagoonal sediment.

C. Acoustic depth soundings

Depth soundings were gathered along transects between survey sites using Hydrobox (Syqwest Inc.), a single-beam acoustic transducer that emits 3 pings per second. Depths were measured 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 thespectral attenuation of light in the water column. The final topographic map will have the same spatial resolution as the satellite imagery.

Coral Reef Assessments

A. Fish assessments

Fish abundance and size structure were collected for over 400 species of fishes (Appendix 1), focusing on species that have a major functional role on reefs or are common fisheries targets. Reef fishes were assessed along 4 m X 30 m belt transects. A T square marked in 5 cm increments was used to gauge fish size. A minimum of 6 transects is 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. Surveys were performed at shallow (3-8 m depth) and mid-depth (9-15 m depth) locations.

Fig. 34. A scientist conducting a reef fish assessment. Image by Ken Marks

B. 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 either recorded observations and/or photographic assessments. Recorded observations involved a point intercept method, whereas the organism and substrate were identified every 10 cm along a 10 m transects (total 100 points/transect), with a minimum of six transects examined per location/depth.

C. Photographic assessment

A 10 m long transect tape was extended along depth contours at 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, the size (planar surface area) of corals are currently being assessed. Cover is determined by recording the benthic attribute located directly below random points (30- 50 points per photograph), using Coral Point Count (CPCe) software developed by the National Coral Reef Institute (NCRI). This software also allows you to trace the outline of individual corals to determine their planar surface area.

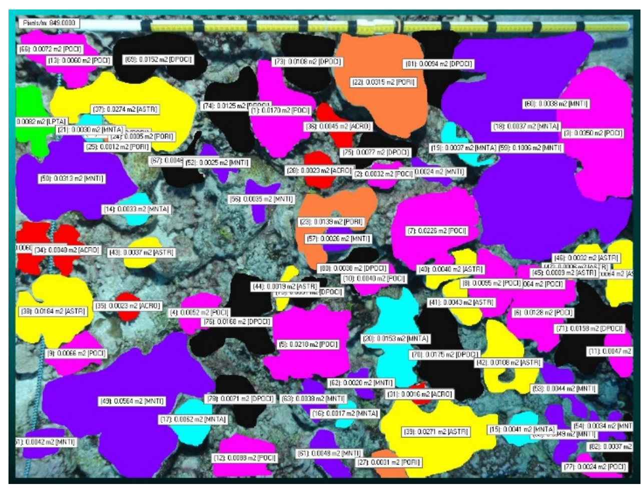


Fig. 35. Example of a photo-quadrat analyzed using CPCe software.

D. 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; 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 done 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 right and left side of the transect. 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.

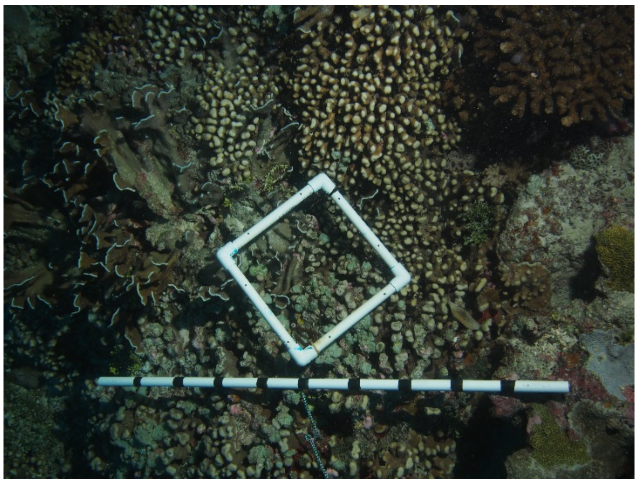


Fig. 36. A 25 cm X 25 cm quadrat was used to assess recruits and a 1 m bar marked in 10 cm increments was used to gauge the width of the belt transect.

Coral population structure and condition is assessed within belt transects (each 10 m x 1 m), with a minimum of two transects done per depth. Each coral, 4 cm orlarger was identified (to genus at minimum) and itsgrowth form is recorded. Visual estimates of tissue loss is 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 is categorized as recentmortality (occurring within the last 1-5 days), transi-tional mortality (filamentous green algae and diatomcolonization, 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, medial) and pattern of tissue loss (linear, annular, focal, multifocal, and coalescing) was recorded and when possible a field name was assigned.

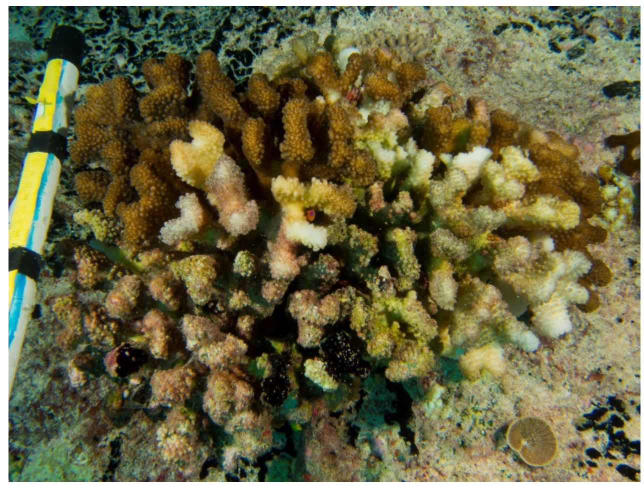


Fig. 37. A colony of Pocillopora with bleached tissue, disease, recent mortality and old mortality.

E. 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 diver conducted timed swims at different depths todocument the species diversity and abundance of seacucumbers at each site assessed. This assessment included a documentation of the type of habitat occupied by these organisms.

F. Physical measurements

On every dive, a profile of the water temperature and salinity was taken from the surface of the water to the reef.

Schedule

Day	Date	Location	Notes
Sat-Sun	7-8 Mar	Transit from Male to BIOT	Scientists arrive 6-7 Mar, 687' transit
Sun-Mon	8-9 Mar	Cauvin Bank	No anchorage at Cauvin Bank, drifting
Tue-Wed	10-11 Mar	Egmont Islands	No anchorage at Egmont, , drifting
		Great Chagos Bank	
Thu-Sat	12-14 Mar	Danger Islands	Anchorage: 06°23.5'S 071° 15.1'E
Sun-Tue	15-17 Mar	Eagle Islands	Anchorage: 06°11.5'S 071°20.5'E
Wed-Tue	18-24 Mar	Three Brothers	Anchorage: 06°09.4'S 071°32.4'E
Wed-Sat	25-28 Mar	Central Chagos	Anchorage: 06°08.2'S 071°31.3'E
	29-30 Mar	Transit back to Male	
Sun-Mon	12-13 Apr	Transit from Male to BIOT	Scientists arrive 11-12 Apr, 594' transit
Tue-Thu	14-16 Apr	Peros Banhos	Anchorage: 05° 15.8S 071° 45.9E
Fri-Sun	17-19 Apr	Peros Banhos	Anchorage: 05° 16.1S 071° 56.5E
Sun-Mon	19-20 Apr	Peros Banhos	Anchorage: 05° 26.8S 071° 46.1E
Tue-Wed	21-22 Apr	Nelson Island	Anchorage: 05° 41.3S 072° 18.9E
Tue	21-Apr	Victory Bank	Shadow transits to Salomon
Wed-Sun	22-26 Apr	Salomon Island	Anchorage: 05°19.2'S 072° 15.0'E
Wed-Thu	22-23 Apr	Blenheim Reef	Calcutta transits from Salomon
Fri, Sun	24,26 Apr	Speakers Bank	Shadow drifts offshore, then returns to Salomon
Mon	27-Apr	Victory Bank	One dive enroute to Diego Garcia
Tue	28-Apr	Speakers Bank	Shadow drifts offshore, then returns to Salomon
Tue-Thu	28-30 Apr	Salomon Islands	Anchorage: 05°19.2'S 072° 15.0'E
Thu	30 Apr	Victory Bank	Shadow transits to Peros Banhos
Fri-Sun	1-3 May	Peros Banhos	Anchorage: 05° 26.8S 071° 46.1E
Sat	2 May	Blenheim	Lagoonal dive, twin V transits to and from Peros Banhos
Mon	4 May	Transit from BIOT to Male	Scientists depart 6 May

Table 1. Final schedule for the coral reef research missions to BIOT, March-May 2015.

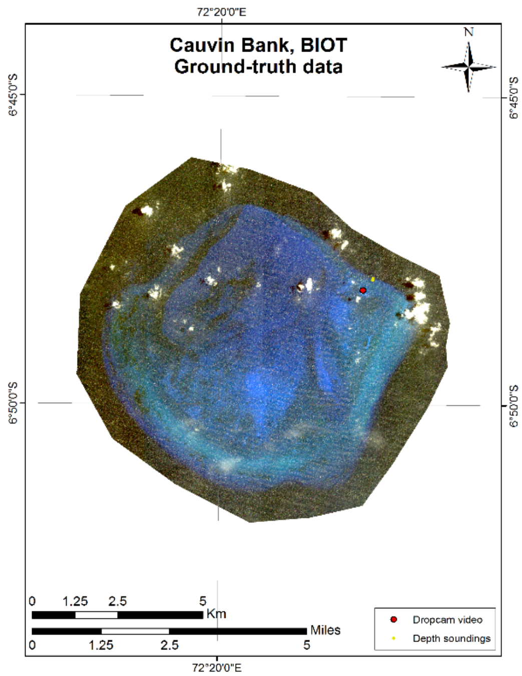
Habitat Mapping

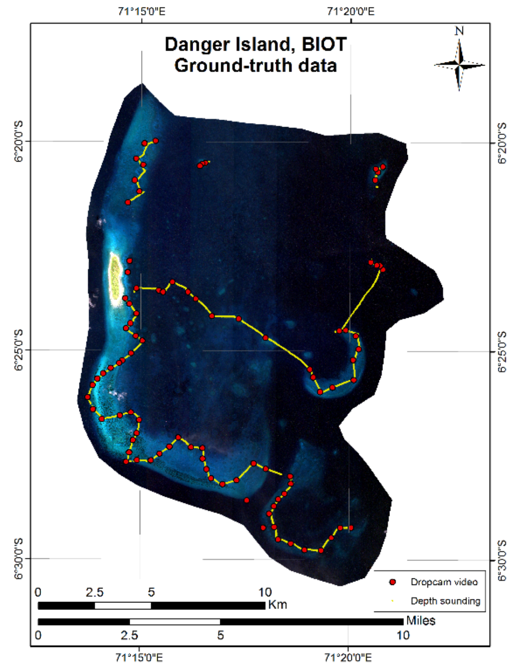
Groundtruthing efforts were concentrated in lagoonal areas, leeward side of fore environments, and windward sides, except during rough weather. In many cases, a trackwas run close to the reef crest on the outside of the reef, but near vertical surfaces limited the extent ofdrop camera deployment and bathymetric soundings because the water depth exceeded the resolution of the satellite imagery and standard depths of habitat mapping (25 m).

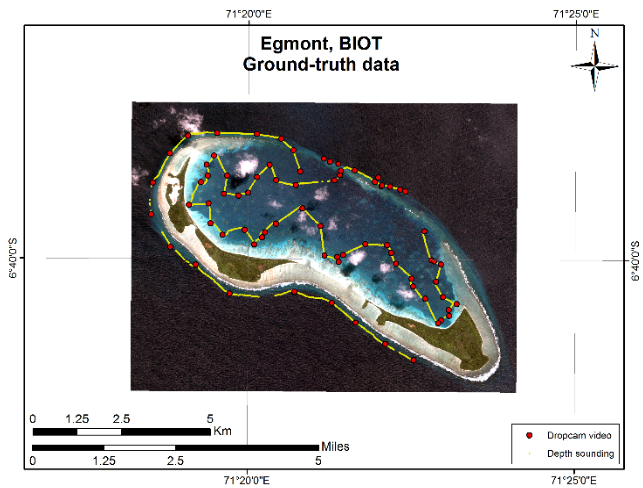
A summary of the satellite imagery and groundtruthing data collected is shown in Table 2. Maps of the track of the groundtruthing vessel are shown for each atoll and bank on subsequent pages.

Location	Area of Imagery (km^2)	Number of Drop Cameras	Number of Sediment Samples	Number of Bathymetry Soundings	Distance Sampled (km)
Cauvin Bank	86	0	1	889	0.05
Egmont Island	53	76	4	257,763	25.93
Danger Island	240	93	5	314,503	51.50
Eagle Island	317	127	3	458,369	72.08
Three Brothers	1,297	240	20	878,701	51.97
Central Chagos	436	82	0	287,462	168.40
Peros Banhos	574	214	13	728,527	142.64
Nelson Island	161	58	5	212,161	43.29
Blenheim	67	59	6	278,832	44.82
Victory Bank	29	29	0	112,086	21.35
Salomon	54	86	7	346,927	49.68
Speakers Bank	632	141	0	583,746	114.97
TOTAL	3089	760	62	3,458,261	583.29

Table 2. Summary of the groundtruthing data for the British Indian Ocean Territory. The total area of imagery, number of drop cameras, sediment samples, bathymetry soundings and distance sampled are shown for each island.







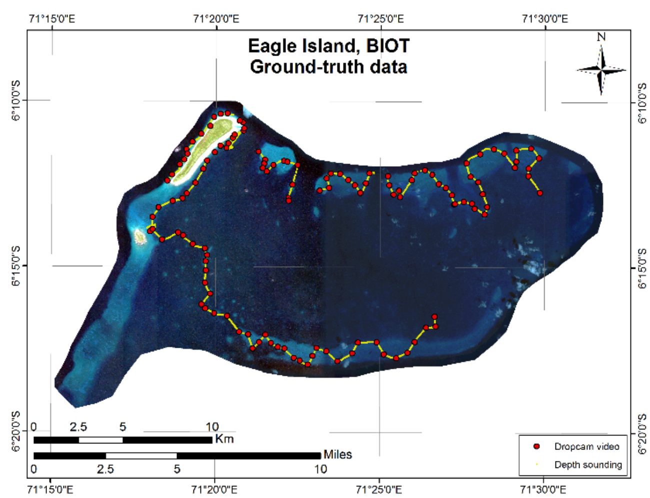
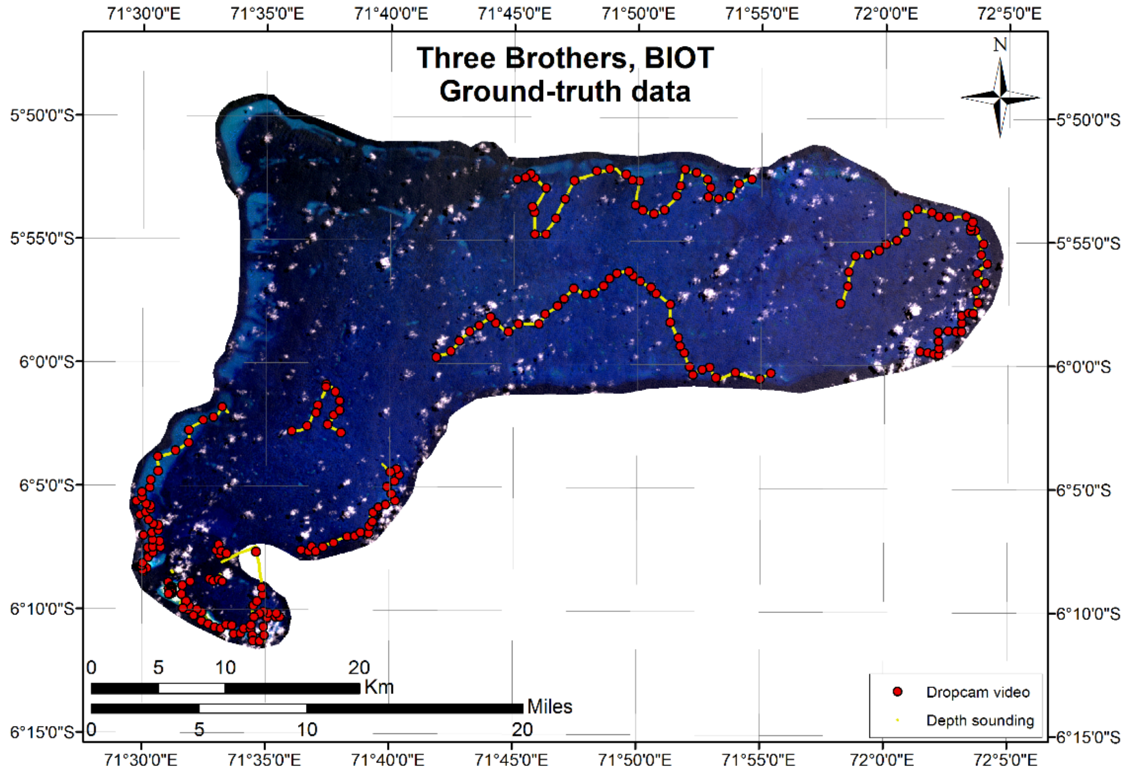


Fig. 38. Track of the research vessel illustrating the locations of bathymetric soundings, drop cameras and sediment samples for Cauvin, Danger Island, Egmont Island and Eagle Island.



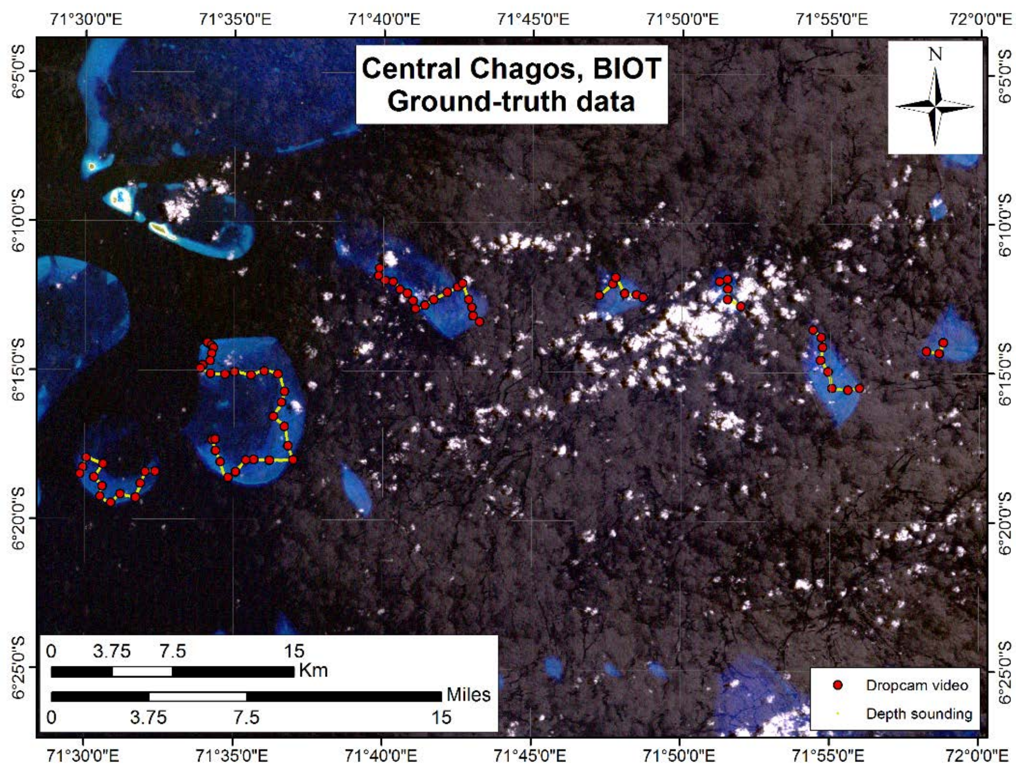
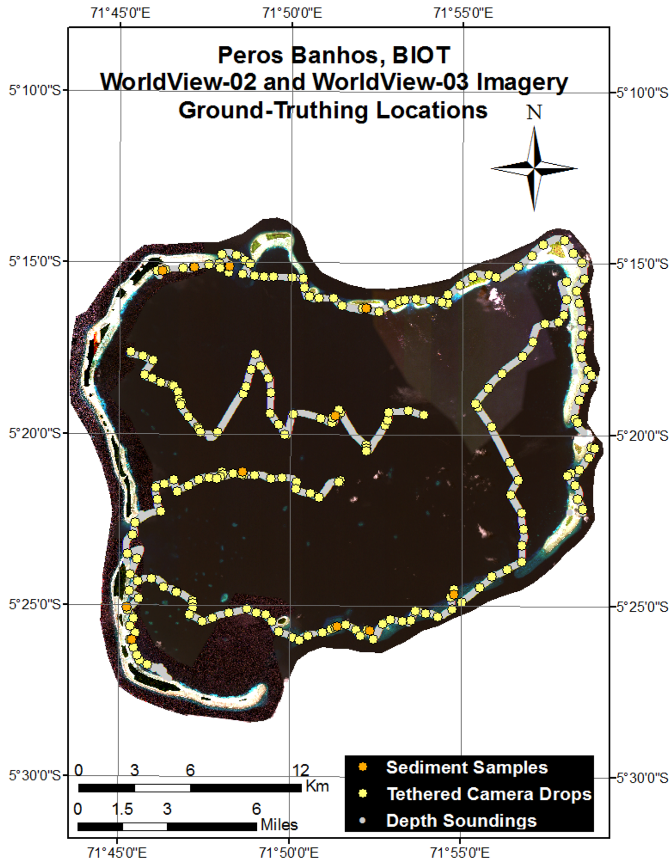
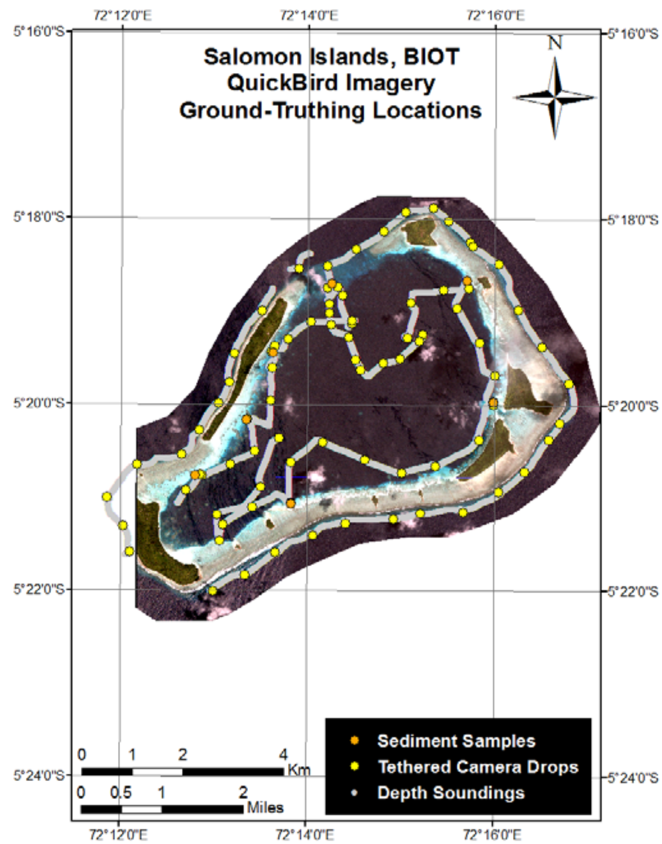


Fig. 39. Track of the research vessel illustrating the locations of bathymetric soundings, drop cameras and sediment samples for Three Brothers and Central Chagos.





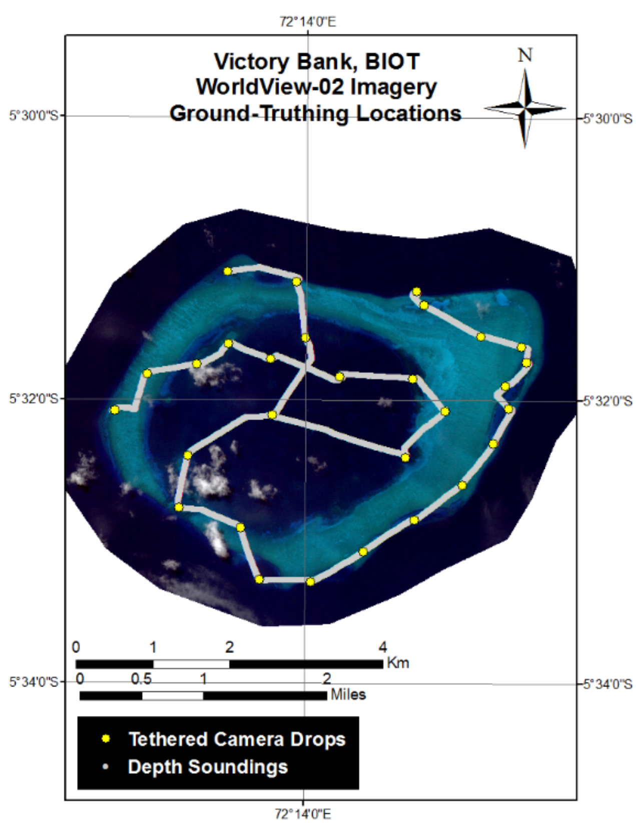


Fig. 40. Track of the research vessel illustrating the locations of bathymetric soundings, drop cameras and sediment samples for Peros Bahnos, Salomon Islands and Victory Bank.

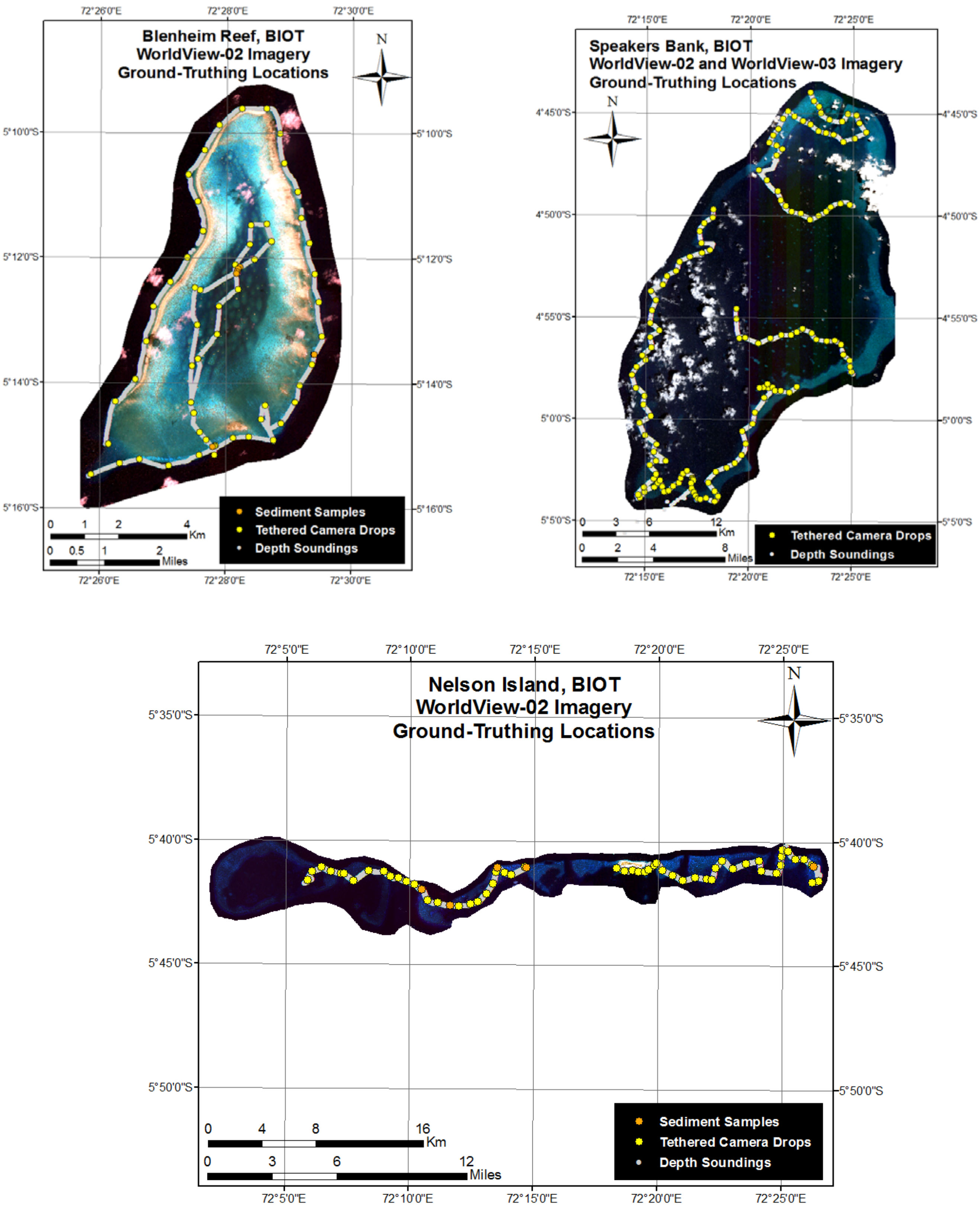


Fig. 41. Track of the research vessel illustrating the locations of bathymetric soundings, drop cameras and sediment samples for Blemhein, Speakers Bank and Nelson Island, Great Chagos Bank.

Coral Reef Assessments

SCUBA surveys were completed on 115 coral reefs within seven regions. Surveys were divided among 11 scientists with three conducting benthic point intercept assessments, three for coral belt transects, four for fish transects and one individual doing photo-transects. Two scientists also completed additional photo-transects and motile invertebrate assessments from 10-30 m depth. Survey locations for the first mission are summarized in Table 3 and the second mission in Table 4. Specific locations are shown in figures on subsequent pages.

Date	Location	Site	Latitude	Longitude
3/9/2015	Cauvin	BICA01	-6.80368	72.38544
3/10/2015	Egmont	BIEG02	-6.66706	71.39087
	Egmont	BIEG03	-6.69394	71.37862
	Egmont	BIEG04	-6.64751	71.36836
3/11/2015	Egmont	BIEG05	-6.64248	71.31116
	Egmont	BIEG06	-6.63941	71.33949
	Egmont	BIEG07	-6.66732	71.36813
3/12/2015	Danger Island	BIDI08	-6.39417	71.23412
	Danger Island	BIDI09	-6.37934	71.23359
	Danger Island	BIDI10	-6.39078	71.24618
	Danger Island	BIDI11	-6.48727	71.29902
3/13/2015	Danger Island	BIDI12	-6.4534	71.2337
	Danger Island	BIDI13	-6.46106	71.24386
	Danger Island	BIDI14	-6.40987	71.25622
3/14/2015	Danger Island	BIDI15	-6.3531	71.2358
	Danger Island	BIDI16	-6.34088	71.25667
	Eagle Island	BIEA17	-6.18099	71.34828
3/15/2015	Eagle Island	BIEA18	-6.2024	71.4042
	Eagle Island	BIEA19	-6.202	71.3588
	Eagle Island	BIEA20	-6.1899	71.3633
	Eagle Island	BIEA21	-6.2047	71.4163
3/16/2015	Eagle Island	BIEA22	-6.27659	71.27627
	Eagle Island	BIEA23	-6.24221	71.29063
	Eagle Island	BIEA24	-6.20961	71.30426
3/17/2015	Eagle Island	BIEA25	-6.19072	71.31839
	Eagle Island	BIEA26	-6.17221	71.33191
	Three Brothers	BITB27	-6.15622	71.50993
3/18/2015	Three Brothers	BITB28	-6.1384	71.5091
	Three Brothers	BITB29	-6.13459	71.49796
	Three Brothers	BITB30	-6.16396	71.53207
	Three Brothers	BITB31	-6.14589	71.53055

Date	Location	Site	Latitude	Longitude
3/19/2015	Three Brothers	BITB32	-6.17152	71.59340
	Three Brothers	BITB33	-6.17930	71.58126
	Three Brothers	BITB34	-6.16935	71.54637
3/20/2015	Three Brothers	BITB35	-6.18385	71.64028
	Three Brothers	BITB36	-6.23205	71.58827
	Three Brothers	BITB37	-6.17699	71.54402
	Three Brothers	Night Dive	-6.16866	71.54061
3/21/2015	Three Brothers	BITB38	-6.16828	71.54042
	Three Brothers	BITB39	-6.17145	71.53494
	Three Brothers	BITB40	-6.14811	71.52852
3/22/2015	Three Brothers	BITB41	-6.02997	71.54900
	Three Brothers	BITB42	-6.05761	71.52129
	Three Brothers	BITB43	-6.10527	71.49875
3/23/2015	Three Brothers	BITB44	-6.03978	71.55077
	Three Brothers	BITB45	-6.05076	71.53503
	Three Brothers	BITB46	-6.09610	71.5143
3/24/2015	Three Brothers	BITB47	-6.02659	71.61644
	Three Brothers	BITB48	-6.06785	71.67516
	Three Brothers	BITB49	-6.11030	71.65470
3/25/2015	Three Brothers	BITB50	-6.39945	71.61726
	Three Brothers	BITB51	-6.30018	71.56963
	Three Brothers	BITB52	-6.19878	71.49310
3/26/2015	Three Brothers	BITB53	-6.12684	71.50318
	Three Brothers	BITB54	-6.16601	71.52676
	Three Brothers	BITB55	-6.17526	71.53974
3/27/2015	Three Brothers	BITB56-a	-6.17943	71.56844
	Three Brothers	BITB56-b		
	Three Brothers	BITB57-a	-6.15979	71.52710
	Three Brothers	BITB57-b	-6.16313	71.52572
3/28/2015	Three Brothers	BITB57-c	-6.16175	71.52640
	Three Brothers	BITB58	-6.14790	71.52411

Table 3. Coordinates of survey locations during the first mission.

Date	Location	Site	Latitude	Longitude
4/14/2015	Peros Banhos	BIPB60	-5.44336	71.74987
	Peros Banhos	BIPB61	-5.39123	71.74974
	Peros Banhos	BIPB62	-5.42721	71.77779
4/15/2015	Peros Banhos	BIPB63	-5.41518	71.77499
	Peros Banhos	BIPB64	-5.46244	71.82438
	Peros Banhos	BIPB65	-5.41077	71.80349
4/16/2015	Peros Banhos	BIPB66	-5.38130	71.75180
	Peros Banhos	BIPB67	-5.28098	71.73499
	Peros Banhos	BIPB68	-5.25630	71.76861
	Peros Banhos	BIPB69(a)	-5.29642	71.76703
4/17/2015	Peros Banhos	BIPB69(b)	-5.29642	71.76703
	Peros Banhos	BIPB70	-5.32515	71.85739
	Peros Banhos	BIPB71	-5.25511	71.81393
4/18/2015	Peros Banhos	BIPB72	-5.27607	71.88663
	Peros Banhos	BIPB73	-5.26732	71.88862
	Peros Banhos	BIPB74	-5.26106	71.95179
4/19/2015	Peros Banhos	BIPB75	-5.30500	71.97903
	Peros Banhos	BIPB76	-5.33774	71.98058
4/20/2015	Nelson Island	BINI77	-5.70590	72.32407
	Nelson Island	BINI78	-5.68049	72.38146
	Nelson Island	BINI79	-5.68903	72.32247
4/21/2015	Nelson Island	BINI80a	-5.71253	72.04568
	Nelson Island	BINI80b	-5.71213	72.04500
	Victory Bank	BIVB81	-5.53439	72.21585
4/22/2015	Blenheim	BIBL82	-5.25432	72.45724
	Blenheim	BIBL83	-5.21858	72.49256
	Salomon	BISA84	-5.31730	72.22408
	Salomon	BISA85	-5.32487	72.24976
4/23/2015	Blenheim	BIBL86	-5.17795	72.45708
	Blenheim	BIBL87	-5.23198	72.44305
	Salomon	BISA88	-5.33932	72.23605
4/24/2015	Speakers Bank	BISP89	-4.95175	72.38296
	Speakers Bank	BISP90	-4.95045	72.41215
	Salomon	BISA91	-5.33965	72.26332
4/25/2015	Salomon	BISA92	-5.32886	72.28001
	Salomon	BISA93	-5.29926	72.25788
	Salomon	BISA94	-5.35038	72.22001
4/26/2015	Speakers Bank	BISP95	-5.04994	72.28725
	Speakers Bank	BISP96	-4.96593	72.23623

Date	Location	Site	Latitude	Longitude
4/26/2015	Salomon	BISA97	-5.31676	72.23729
	Salomon	BISA98	-5.32422	72.21898
4/27/2015	Victory Bank	BIVB99	-5.53102	72.24508
4/28/2015	Speakers Bank	BISP100	-4.78432	72.34454
	Speakers Bank	BISP101	-4.79250	72.34557
	Salomon	BISA102	-5.36938	72.21379
4/29/2015	Salomon	BISA103	-5.34896	72.26869
	Salomon	BISA104	-5.30829	72.26865
	Salomon	BISA105	-5.33426	72.24311
	Salomon	BISA106	-5.34425	72.20390
4/30/2015	Salomon	BISA107	-5.31024	72.26888
	Victory Bank	BIVB108	-5.52648	72.22646
	Victory Bank	BIVB109	-5.54759	72.21877
	Peros Banhos	BIPB110	-5.31748	71.92240
5/1/2015	Peros Banhos	BIPB70b	-5.32432	71.85711
	Peros Banhos	BIPB72b	-5.27660	71.88622
	Peros Banhos	BIPB74b	-5.26043	71.95177
	Peros Banhos	BIPB111	-5.387	71.94584
5/2/2015	Peros Banhos	BIPB69c	-5.29669	71.76605
	Peros Banhos	BIPB112	-5.2373	71.962
	Blenheim	BIBL113	-5.20824	72.47023
	Peros Banhos	BIPB114	-5.25724	71.97576
5/3/2015	Peros Banhos	BIPB114b	-5.25724	71.97576
	Speakers Bank	BISP115	-4.91949	72.43696

Table 4. Coordinates of survey locations in BIOT during the second mission

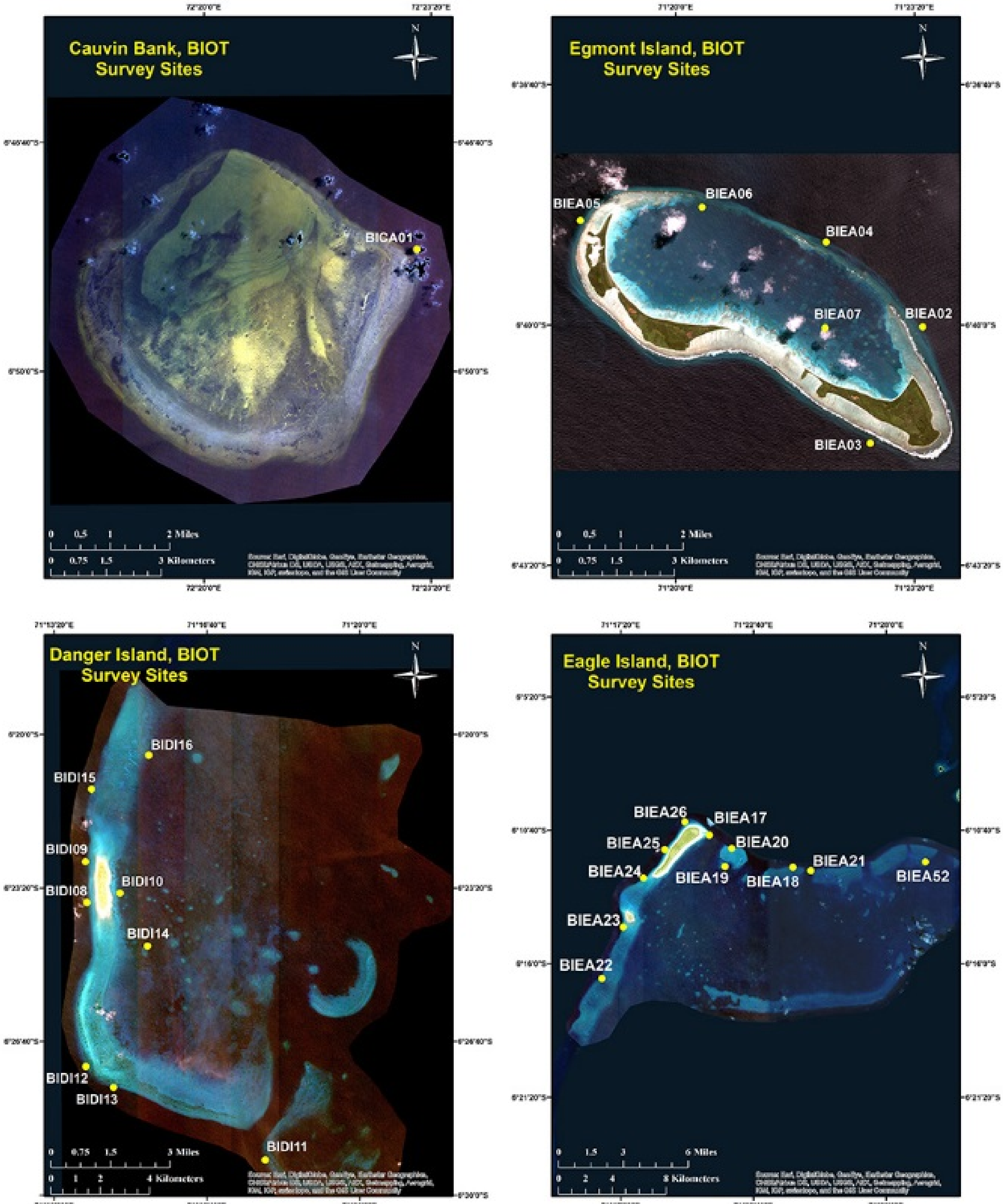


Fig. 42. Survey locations within the vicinity of Cauvin Bank, Egmont Island, Danger Island and Eagle Island.

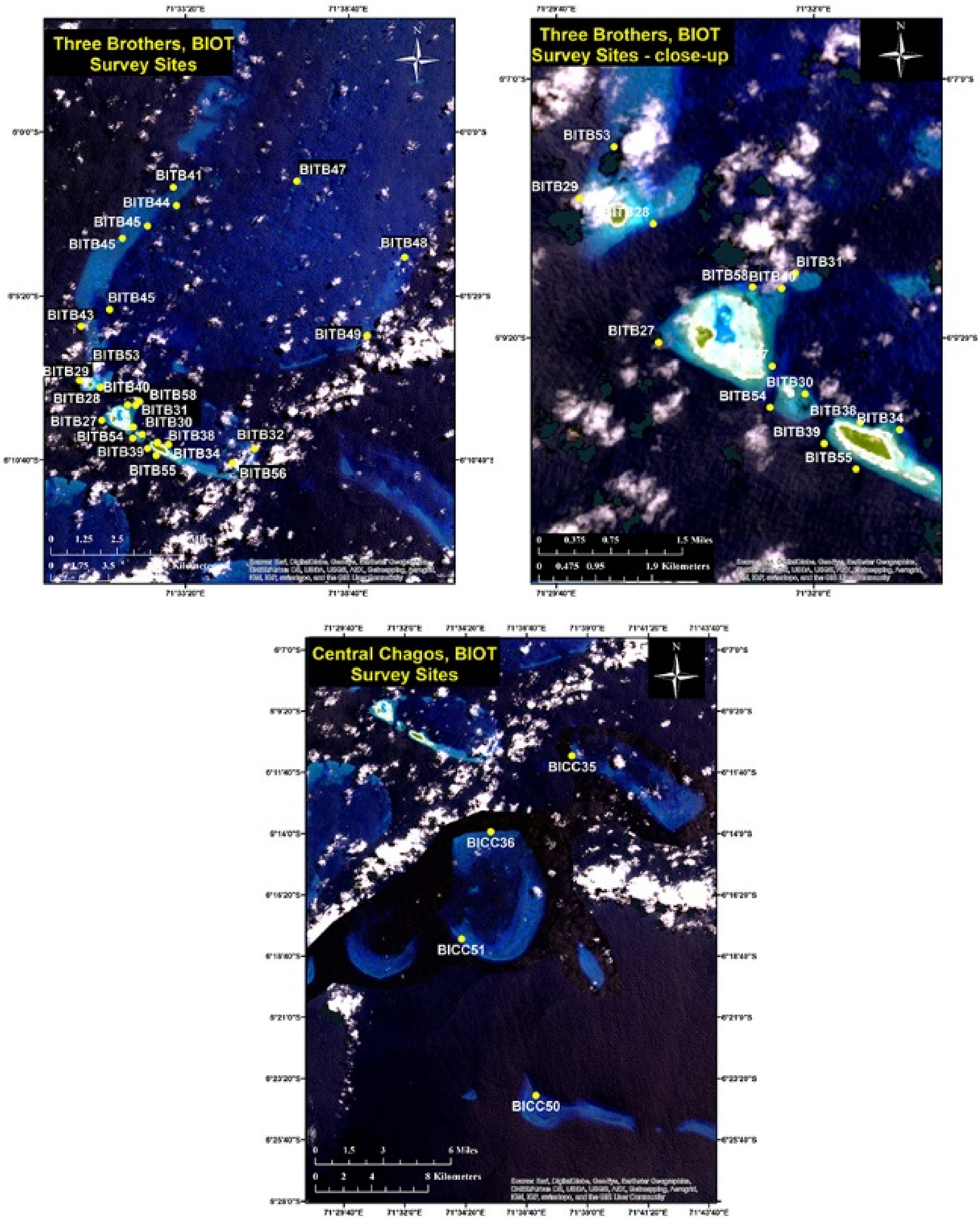


Fig. 43. Survey locations near Three Brothers, Great Chagos Bank.

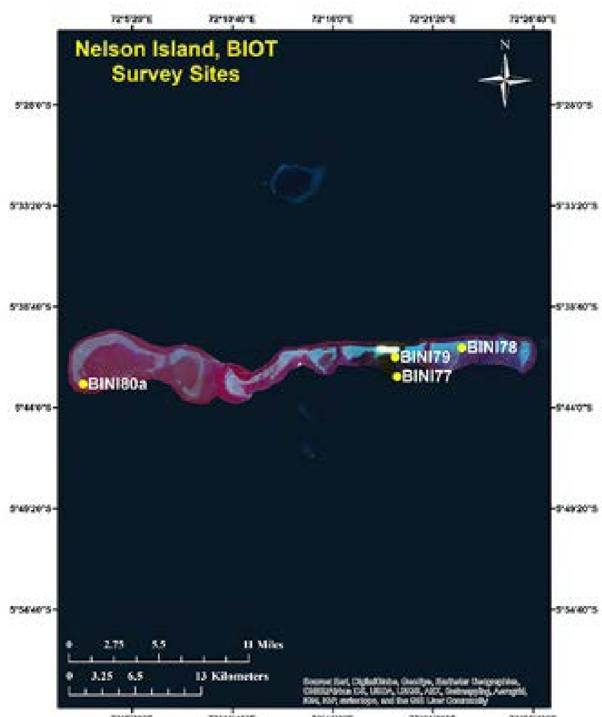


Fig. 44. Survey locations at Peros Bahnos and Nelson Island, Great Chagos Bank.

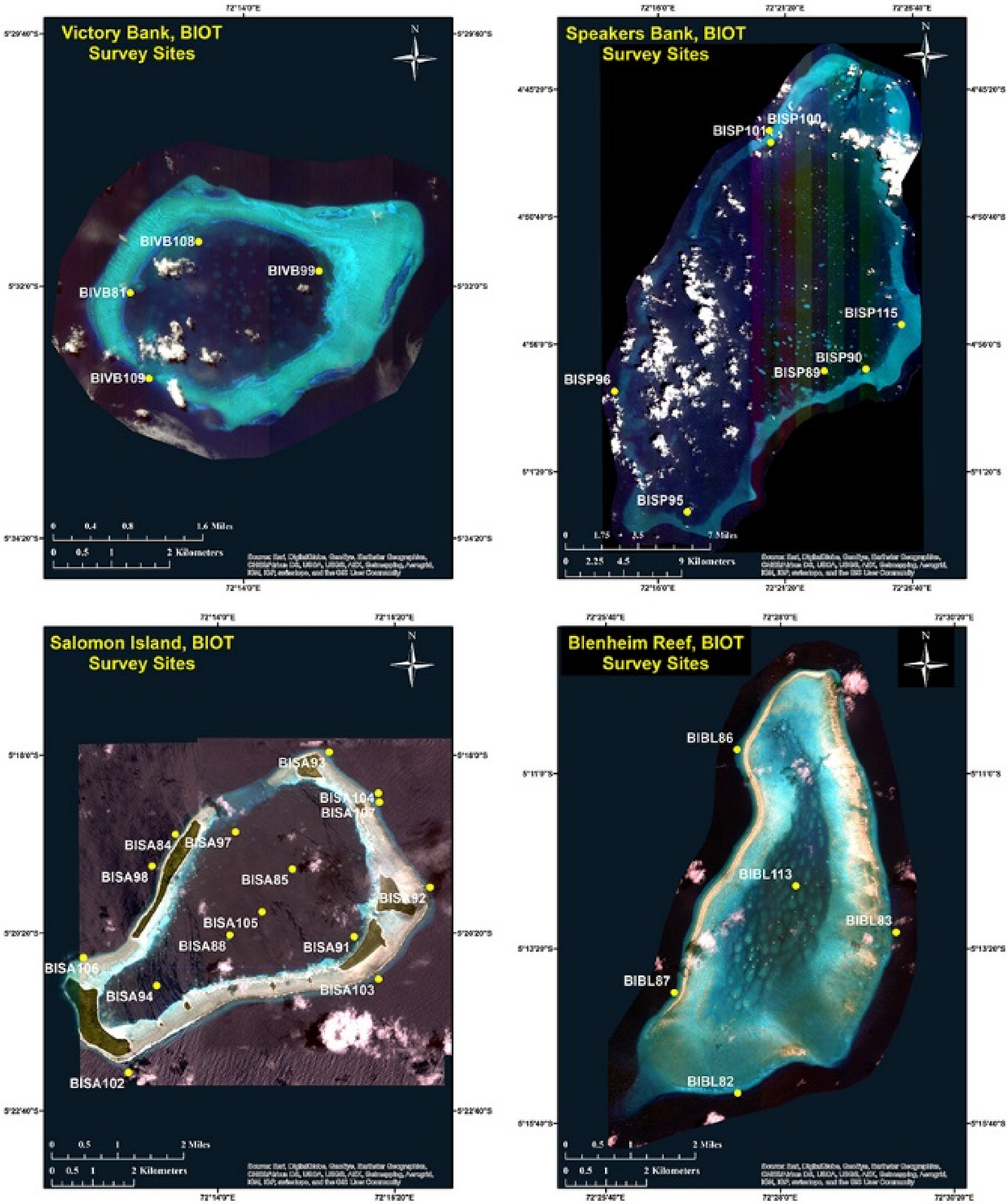


Fig. 45. Survey locations at Speakers (top left), Salomon (top right), Blenheim (bottom left) and Victory Bank (bottom right).

Coral Reef Research

Research at BIOT focused on five indicators of the health and resilience of Chagos Reefs. Specific projects included 1) an assessment of the condition of reef building corals, focusing on the prevalence and impacts of coral diseases and corallivores; 2) ocean acidification and relationships between coral growth and pH, CO_2 concentration and alkalinity; 3) measurement of sub-lethal levels of stress in *Pocillopora*; 4) composition and type of symbionts contained within *Pocillopora* colonies from different locations and depths; and 5) past climate records for BIOT, based on an assessment of trace element ratios within the skeletons of *Porites*.

Coral condition

Photo-transects, point intercept surveys and coral belt transects were used to assess the composition of corals, size structure, amount of recent and old mortality and condition. From these surveys, the percent of corals affected by diseases, predation scars and bleaching will be calculated. Coral bleaching is subdivided into five categories (normal, pale, completely bleached, patchy bleaching, partial bleaching).

An unusual pattern of tissue mortality was detected in a high prevalence of *Pocillopora* colonies. The field signs of this condition included a pale or bleached band of tissue adjacent to live tissue, followed by a narrow band of recent mortality. Some colonies have old mortality and recent mortality, with recent mortality advancing from the bases of the branches to the tips. On each reef, all colonies over 5 cm diameter located within a 10 X 50 m belt were photographed to determine the size structure and any relationships between disease and colony size, prevalence of the disease, and amount of tissue loss.

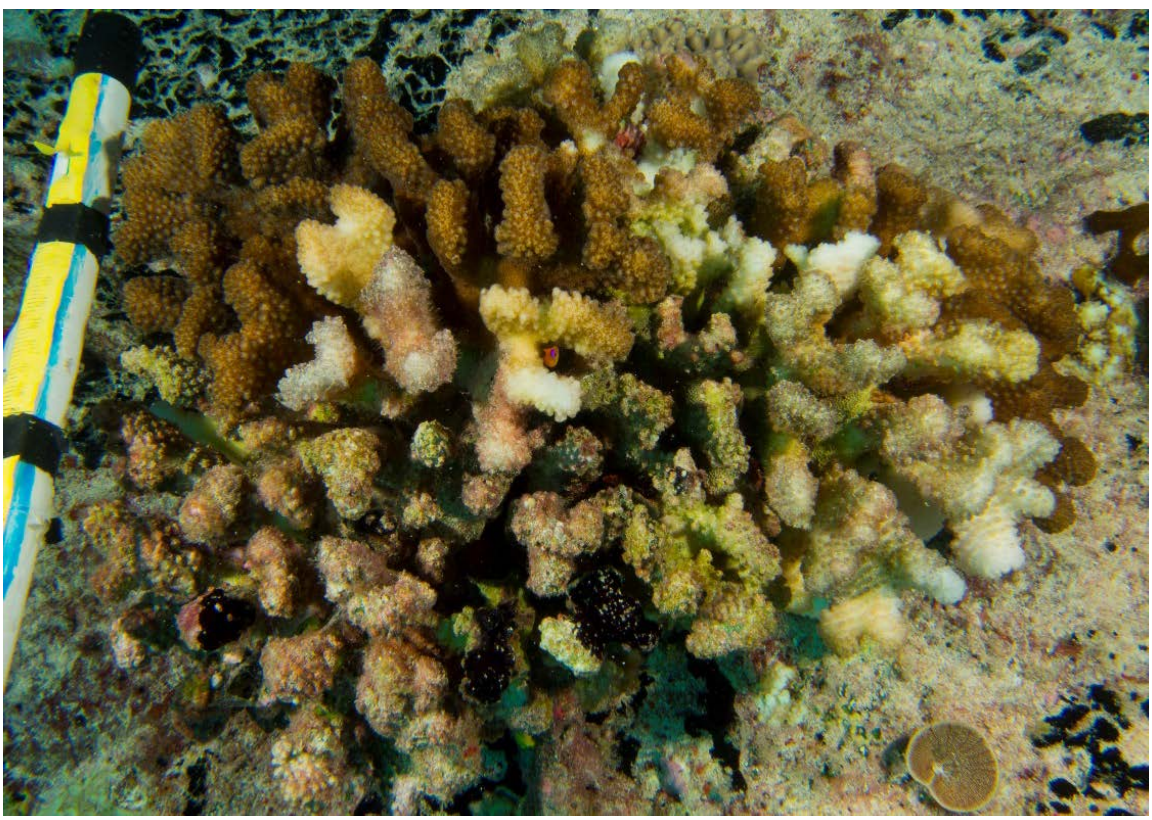


Fig. 46. Colony of Pocillopora verrucosa with signs of old mortality, bleaching and recent mortality.

The Levels of Acidification of Seawater and Impacts on Coral Communities

Oceanographic measurements taken during the BIOT research missions included 1) CTD casts at each survey location, prior to the SCUBA assessments;
2) measurements of CO_2 at each survey location; and
3) longer term (1-5 day) measurements of pH on an individual reef in each island/atoll. To assess the baseline CO_2 concentration and pH in BIOT, continuous measurements of surface waters were taken over the duration of the 65 minute dive at each survey location.

Three to four seawater bottle samples (500 ml) were also collected from each site visited. Seawater samples were preserved with 2 µl of saturated $HgCl_2$ and sealed with large rubber bands to prevent any changes to the carbonate system before analysis. Total CO_2 (TCO2) is being measured coulometrically and total alkalinity (TA) measured utilizing a gran titration by Dr. Derek Manzello (NOAA/AOML) in their laboratory in Miami, Florida (USA).

An autonomous pH sensor (Satlantic SeaFET pH meter) was placed on the seafloor, for durations of a few hours to multiple days depending on the time spent in each region. Typically, the SeaFET was deployed at one site per island. The SeaFET was set to take a measurement every 15 or 30 minutes and was deployed at approximately 10 meters depth.

Measurements of CO_2 (µmol/mol) in seawater were made by pumping sea-surface water through an equilibrator system to release the carbon dioxide dissolved in seawater. The gas was then measured using a calibrated Li-Cor 820 CO_2 gas analyzer. The instrument ran continuously for approximately 1 hour at each site and the output values were then averaged for each site. These parameters allowed calculation of the carbonate system of seawater (i.e., partial pressure of CO_2 (pCO_2), pH and Ω).

Island	No. cores
Cauvin	0
Egmont Island	5
Danger Island	11
Eagle Island	14
Three Brothers	33
Peros Banhos	20
Nelson Island	5
Victory Bank	3
Blenheim Reef	4
Salomon Island	13
Speakers Bank	6
Total	114

Table 5 Cores removed from Porites lobata/lutea for growth rate measurements.

Fig. 47. Removing a core from Porites lobata with a pneumatic drill.

Fig. 48. Core removed from Porites lobata. The diver fills the core hole with underwater putty to allow the coral to resheet over the plug.

Fig. 49. Sampling a colony of Pocillopora damicornis. A small nubbins is removed using clippers. Image by Joao Monteiro.

Symbiont Composition in *Pocillopora*

This component involved the sampling of colonies of *Pocillopora* from different habitats, depths and locations to characterize their symbionts. In each location, a diver started at 30 m and progressively worked up to 5 m depth, sampling a minimum of three pocilloporid corals per depth gradient (5, 10, 15, 20, 25, and 30 m).

Fragments were placed in individual zip-lock bags underwater and then transferred to vials containing DMSO and stored in a -20° C freezer. Typical biopsies are <0.5 cm^2 in total surface area, and are removed from host colonies using pincers or clippers from branching colonies in the genus *Pocillopora*. The total amount of tissue removed is less than that taken by a single fish bite. A total of 3 samples are collected per colony, with up to 30 samples collected per site and 310 collected over the two research missions (Table 6).

Pocillopora Samples	
Atoll/Bank	No. Samples
Cauvin Banks	6
Egmont	14
Danger Islands	28
Eagle Island	28
Three Brothers	81
Peros Banhos	60
Nelson Island	8
Great Chagos	4
Victory Bank	12
Blenheim Reef	17
Speaker's Bank	28
Salomon Island	24
Total	310

Table 6. Samples of Pocillopora spp. collected for Symbiodinium assessment. All samples (approx.. 1 cm^3) were preserved in 20% DMSO solution at -20ºC.

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 that can 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. *Seriatopora* was also sampled because this taxa has been showing paling, bleaching and high rates of mortality throughout much of the Indo-Pacific during 2014-2015.

In each location, replicate samples of *Pocillopora damicornis* and *Seriatopora* spp. were identified at different depths (5-30 m). The colonies were first assessed for visible signs of stress. A small biopsy (100 mg) consisting of 3-5 polyps is removed from a branch tip using clippers shown in Fig. 50. The sample was divided in half: 50% for molecular work, 50% for microscopy. Half the sample was placed in RNA Later® or frozen in liquid nitrogen; the other half was fixed in paraformaldehyde and decalcified. All processing will be done in the laboratory in Taiwan. Total number of samples collected are shown in Table 7.

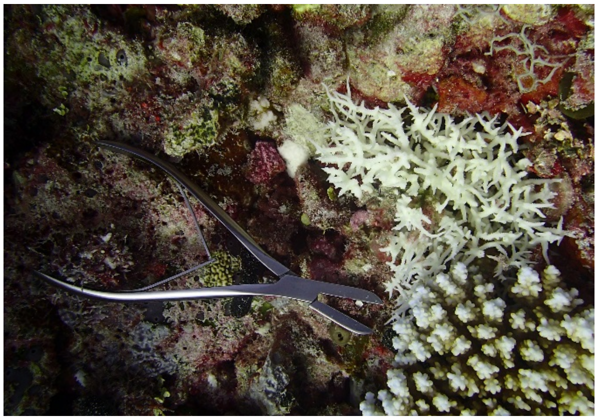


Fig. 50. A bleached colony of Seriatopora that was sampled. This taxa was relatively uncommon and formed large thickets only in a few lagoonal locations. Image by Anderson Mayfield.

Atoll/Bank	*Pocillopora damicornis* number	*Seriatopora* number
Cauvin Banks	0	0
Egmont	12	2
Danger Islands	3	0
Eagle Island	0	3
Three Brothers	46	55
Peros Banhos	59	49
Nelson Island	0	3
Great Chagos	0	4
Victory Bank	1	7
Blenheim Reef	0	12
Speaker's Bank	2	8
Salomon Island	41	27
Total	164	170

Table 7. Total number and weight of tissue/skeletal samples collected from Pocillopora damicornis and Seriatopora spp. for biomarker and health assessment.

Reconstruction of past climate

The overarching goal of this proposed work is to obtain long coral drill cores from *Porites lobata* and *Porites lutea* colonies from remote locations in the southern tropical Indian Ocean for reconstruction of decadal-centennial patterns of climate change. BIOT is situated along the southern edge of ITCZ migration and is an ideal location to monitor southern ITCZ variability back through time.

The research team spent considerable time searching for appropriate colonies to sample. Their goal was to find massive *Porites* coral colonies up to 6 m in height, and remove individual cores of equal length from these colonies. They were unable to find colonies of this size during the first mission. Most larger colonies consisted of numerous discontinuous sheets or mounds, and were often bioeroded.

The corals they were able to successfully core were up to 1.5 m height. Cores from these colonies were obtained using an underwater hand-held hydraulic drill and SCUBA. The drill system they used operated using seawater as the hydraulic fluid (in lieu of vegetable oil), eliminating potential impact to the coral reefs.

Fig. 51. The drill apparatus on a Porites colony. Image by Konrad Hughen.

For each core that was removed, the coral boreholes were capped at the colony surface with concrete plugs, thereby allowing the living tissue to grow over the plug. Past efforts using these methods has shown that the scar disappears within approximately one year.

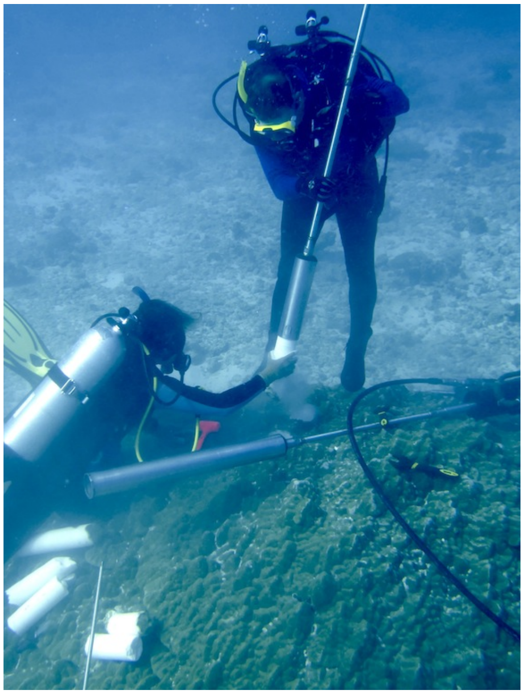


Fig. 52. Removing the cores. Image by Konrad Hughen.

After the cruise, coral cores were returned to the laboratory at WHOI for geochemical analysis. Trace element ratios (Sr/Ca) are a well-documented proxy for sea surface temperature, and oxygen isotopes can be combined with Sr/Ca to provide estimates of salinity. Finally, Ba/Ca ratios are an indication of terrigenous input from rivers or eolian dust. Samples will be taken at 0.5 mm increments, reflecting climate variability at up to bi-weekly resolution and on a range of time scales from interannual to decadal to centennial.

Fig. 53. A core from an individual coral. Image by Konrad Hughen.

Fig. 54. Science team during the first BIOT mission. Left to right front row: Andrew Bruckner, Justin King, Alexandra Dempsey. Second row: Justin Ossolinski, Coleen Hansel, Konrad Hughen, Lauren Valentino. Back row: Jeremy Kerr, Luis Ramirez, Gideon Butler, Kristen Stolberg, Samantha Clements, Georgia Coward, Katie Lubarsky, Stefan Andrews, Badi Samaniego, Anderson Mayfield and Ken Marks.

Scientific Team

Name	Organization	Role
Philip Renaud	Khaled bin Sultan Living Oceans Foundation	Executive Director
Andrew Bruckner, Ph.D.	Khaled bin Sultan Living Oceans Foundation	Chief Scientist, coral assessments
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Samantha Clements	Scripps Institution of Oceanography	Benthic assessments
Ken Marks	Atlantic and Gulf Rapid Reef Assessment	Coral reef photo-transects
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