Coral Sea Marine Park
Environmental assessment of islands, islets and cays of the southern and central reef systems.
Coral Sea Islands Health Project.
May-June 2022

Report to Parks Australia Division, Department of Climate Change, Energy, the Environment and Water.

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Australian Marine Parks

Queensland Government

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Front cover: Brown noddy *Anous stolidus* within a *Tribulus cistoides* field on North Cay, Willis Islets, Coral Sea Marine Park. Photo. Andrew McDougall © Queensland Government

Back cover: The 2022 team. Photo Alex Gorham © Queensland Government

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February 2023

Contents

Executive summary

Natural value assessments of terrestrial ecosystems and species were conducted within nine reef systems and island groups of the Coral Sea Marine Park (CSMP) between May 24 and June 8, 2022.

Data were collected at the following locations:

Reef/Island system	Sites (V = vegetated)
Cato Reef	Cato Island (V)
Wreck Reefs	West Islet, Hope Cay, Porpoise Cay (V), Bird Islet (V)
Kenn Reefs	South West (Boulder) Cay, Observatory Cay, unnamed cay.
Frederick Reefs	Observatory Cay, Lighthouse Cay
Marion Reefs	Brodie Cay, Paget Cay, Carola Cay
Diamond Islets	East Diamond Islet (V)
Herald Cays	North East Cay (V), South West Cay (V)
Willis Islets	Mid Islet (V), North Cay (V)
Dianne Bank	Sand (Bianca) Cay

These assessments are a continuation of voyages undertaken in November/December 2019 (Hemson et al., 2020) and July 2021 (Chapman et al., 2022).

Expert teams representing Parks Australia Division (PAD) and the Queensland Parks and Wildlife Service and Partnerships (QPWSP) performed the following tasks:

- Map and assess vegetation communities at Cato Island, Porpoise Cay, Bird Islet, Mid Islet and North Cay.
- Collect soil and herbaria specimens.
- Obtain high resolution drone imagery of islands, islets and cays and their adjoining reefs.
- Collect bird breeding effort, population, and diversity data.
- Collect pelagic seabird data.
- Survey for invasive species.
- Assess the integrity and health of each site by completing a standardised “Health Check” and “Island Watch” proforma.
- Remove debris.
- Install signage.

Islands, islets and cays will be referred to as cays through this document.

Vegetation

The vegetation of five cays (Cato Island, Porpoise Cay (Wreck Reef), Bird Islet (Wreck Reef), North Cay (Willis Islets) and Mid Islet (Willis Islets) was surveyed between May 25 and June 6, 2022, during a PAD voyage (referred to as the 2022 voyage throughout this document).

Vegetation was in good condition at the time of the surveys.

The thoroughness of the surveys at these cays was limited by available time and in the case of Cato Island and Mid Islet (Willis Islets), by extreme weather conditions and tidally dependent landing conditions.

Vegetation data was recorded at 112 sites across the five vegetated cays for the purposes of:

- Describing and mapping vegetation communities.
- Obtaining a terrestrial plant species inventory for each cay.
- Ground truthing vegetation patterns on spatially rectified aerial imagery.

High resolution drone imagery captured during the voyage was used in conjunction with the ground truthing field data to produce accurate contemporary vegetation maps for each of the vegetated cays surveyed.

Six permanent BioCondition monitoring sites were established in a range of vegetation communities on four of the vegetated cays (two on Cato Island, two on Bird Islet (Wreck Reef), one on North Cay (Willis Islets) and one on Mid Islet (Willis Islets)). Detailed vegetation surveys (including photo-monitoring) of these sites were completed to:

- Monitor changes over time.
- Provide benchmark reference data for BioCondition assessment for the same vegetation communities throughout the Coral Sea cays.

Data from these BioCondition monitoring sites will complement data obtained from the previous 15 BioCondition monitoring sites established and monitored on other Coral Sea cays during the PAD 1919 (Hemson et al, 2020) and 2021 (Chapman et al, 2022) Coral Sea voyages and the 2020 Willis South Islet survey (Brushe, 2021).

In addition to the written report, the following digital data was provided to PAD:

- Ground truthing site data including GPS coordinates (Excel file and an ESRI shapefile).
- Ground truthing site photographs.
- BioCondition monitoring site data (Excel file).
- Locations and GPS coordinates of the BioCondition monitoring sites (ESRI shapefiles).
- BioCondition monitoring site photographs.
- Vegetation mapping (ESRI shapefile).
- Vegetation map legends (Excel file).

Soil samples were collected from the six monitoring sites for analysis and comparisons with other cays in the CSMP and southern Great Barrier Reef cays.

Vegetation survey data obtained during the 2022 voyage were compared with vegetation survey data recorded on previous surveys where suitable previous data were available.

Plant species richness on the cays was low with a total of 10 plant species native to Coral Sea cays recorded during the voyage.

Native cay vegetation species richness was highest on the Willis islets with 9 species recorded on Mid Islet (Willis Islets) and 8 species on North Cay (Willis Islets) and lowest on Porpoise Cay where only 4 species were recorded.

The May/June 2022 surveys confirmed that all previously recorded plant species are still present on the cays surveyed during this voyage.

Seventeen new species records were documented for the cays surveyed during this voyage:

- three species on Porpoise Cay (Wreck Reef)
- four species on Bird Islet (Wreck Reef) including two weed species
- two species on Mid Islet (Willis Islets)
- eight species on North Cay (Willis Islets).

Three invasive weed species were observed growing on Bird Islet including the introduced grass, *Cynodon dactylon* var. *dactylon* (common couch), which totally dominated approximately 7,000 square meters of vegetation on the northwest section of the cay. The weed species *Solanum americanum* (nightshade) found on Bird Islet during the 2022 voyage, had not previously been recorded anywhere in the Coral Sea Marine Park. The weed species, *Amaranthus viridis* (green amaranth) is a new record for Bird Islet. *Amaranthus viridis* is also present on South Islet (Willis Islets), the only other known location in the Coral Sea Marine Park. These species are commonly occurring invasive weeds on the Southern Great Barrier Reef Cays.

No weeds were observed on any of the other cays visited during the 2022 voyage.

Plant species (all species from each of the vegetated cays surveyed) plus an additional three species from North East Herald and three species from East Diamond Islet) were collected and pressed for incorporation into the Qld Herbarium in Brisbane (44 species), the National Herbarium in Canberra (44 species) and the Tropical Herbarium in Cairns (24) together with the data collected at their collection sites to provide verified records of their current locations and habitat.

No *Pisonia grandis* forests or other tree communities were present on any of the cays surveyed and mapped. A notable change in the vegetation of Cato Island and Mid Islet (Willis Islets) is the establishment of the long-lived, woody shrub, *Argusia argentea* (octopus bush) along their entire shorelines and also in the northwest interior of Mid Islet (Willis Islets). According to earlier reports, only one *Argusia argentea* plant was present on Cato Island in 1979 and only two plants of *Argusia argentea* were present on Mid Islet (Willis Islet) in 1983 and 1984. *Argusia argentea* was not present on any of the other cays surveyed and mapped during the 2022 voyage. The branches of *Argusia argentea* (octopus bush) shrubs provide preferred nesting habitat for red-footed boobies (*Sula sula)*, frigatebirds (*Fregata* spp.) and black noddies (*Anous minutus),* while red-tailed tropicbird (*Phaethon rubricauda*) nest on the ground under the protection of *Argusia argentea* shrubs.

The vegetation of the interior of Cato Island and Mid Islet (Willis Islets) was dominated by herblands, grasslands and occasional low ephemeral shrublands.

Vegetation on Porpoise cay, Bird Islet and North Cay (Willis Islets) consisted entirely of herblands, grasslands and occasional low ephemeral shrublands.

Although small areas of herblands and grasslands are present on the Barrier Reef cays, the herblands of the Coral Sea Cays are much more extensive and are considered regionally and globally important habitat for ground nesting seabirds with little alternative similar habitat available in other regional island groups for the huge numbers of nesting sooty terns (*Onychoprion fuscatus*) and large numbers of brown noddies (*Anous stolidus*) and brown boobies (*Sula leucogaster*) which nest in the herblands and grasslands on the Coral Sea cays. Masked boobies (*Sula dactylatra*) also nest in these herblands and grasslands in low areas adjacent to shorelines.

The unvegetated cays as well as beaches and vegetation free shorelines and sand spits of the vegetated cays provided preferred habitat for predominantly black-naped terns (*Sterna sumatrana*) and masked boobies. Nesting New Caledonian fairy terns (*Sternula nereis exsul*) were also present in this habitat.

Numerous species of drift seeds were collected from beaches and shorelines of both vegetated and non-vegetated cays. Generally vegetated cays had more drift seeds that unvegetated cays and drift seed diversity and numbers of drift seeds were greater in the northern cays than in the southern and central cays, seemingly following the same pattern as quantity of marine debris and other flotsam such as pumice. Drift seeds collected during the voyage have been sent to the Queensland Herbarium and are currently awaiting identification.

With the exception of *Argusia argentea* (octopus bush), none of the species of drift seeds collected were growing on any of the cays. Despite the abundant numbers of *Cocos nucifera* (coconut) drift fruits observed on the cays (including the unvegetated cays), no plants of this species were observed successfully established and growing on any of the cays visited.

Unscheduled opportunistic visits to North East Herald Cay, South West Herald Cay and East Diamond Islet, which were previously surveyed during the 2021, 2021 and 2021 ecological assessment voyages respecitively, provided opportunities to reassess some of the previous survey sites and confirm the absence of weeds on each of these cays.

In the December 2019 survey, patches of *Cordia subcordata* (sea trumpet) on North East Herald were recorded as being of some concern and most plants of this species were apparently dead or close to dead at this time. These patches were revisited during the June 2022 visit and most were found to have new shoots (up to 3m high) Some of the new shoots were severely damaged by leaf eating flying insects.

The shoreline species, *Lepidium englerianum* (beach peppercress), previously recorded on North East Herald Cay but not found during the 2021 survey was observed and collected during the June 2022 visit.

A permanent monitoring site in a shoreline *Argusia argentea* (octopus bush) shrubland that could not be surveyed during the previous visit was able to be more thoroughly surveyed during the opportunistic visit to East Diamond Islet in 2022.

Soils

Soil samples were collected from a range of depths in the A horizon within each of the six BioCondition monitoring sites surveyed during the 2020 voyage. Results of the analysis showed that:

- The soils in the North Cay and Mid Islet (Willis Islets) sites had less soil development, lower nutrient and lower nutrient availability than those at the Cato Island and Bird Islet sites.
- Levels of sulphur were high at all sites sampled during the 2022 voyage.

Soils data are compared for the 2022 sites, 2021 data from the Diamond Islet and Lihou Reef cays, 2020 data from South Islet (Willis Islets), 2006-2008 data from the Coringa Herald cays and 2006/2007 data from the Capricornia Cays in the Southern Great Barrier Reef.

Birds

Survey results reaffirm the Coral Sea Marine Park as critically important for many bird species.

Key Australian populations of the following species were surveyed:

- red-tailed tropicbird *Phaethon rubricauda roseotinctus*
- New Caledonian fairy tern *Sternula nereis exsul*
- great frigatebird *Fregata minor*
- lesser frigatebird *Fregata ariel*
- sooty tern *Onychoprion fuscatus*
- red-footed booby *Sula sula*

Approximately 800 pairs of red-tailed tropicbirds were recorded on the Herald Cays (North East Cay and South West Cay). This is an internationally significant breeding event considering the 1% global population threshold (to signify a site as important) is 700 adults. This survey indicates at least 1600 adults in the Herald Cays group during this breeding event.

Thirty-five New Caledonia fairy terns were recorded on Paget Cay in the Marion Reef system. Thirty-four of these were in full breeding plumage, indicating imminent breeding, probably at Paget Cay. Black-naped terns had started nesting at Paget Cay and are known to share breeding sites with New Caledonian fairy terns (McDougall A. 2022).

No further colonies of Herald petrel *Pterodroma heraldica* were located during this voyage.

A colony greater than 40,000 pairs of sooty terns was observed at North Cay in the Willis Islets group.

Most of the cays are pest and weed free and are not subject to excessive human disturbance. This combination of factors provides a breeding refuge for many species.

Comprehensive surveys at some sites were not possible due to the lush and abundant vegetation. The use of drone imagery was critical in providing a more thorough account of bird diversity and breeding effort.

Opportunistic pelagic (open sea) surveys resulted in some interesting sightings and provided data for seldomly visited sections of the Coral Sea.

Data will be uploaded to Birdlife Australia's "Birdata" platform.

Health Checks

These were the first Health Checks undertaken for cays scheduled in the trip plan. An opportunistic visit to North East Cay in the Herald Cays group allowed for a second round of Health Checks to complement the first completed in November 2019.

The overall condition rating for vegetated cays in the central and southern reef systems was Good. The exception being Bird Islet with a rating of Significant Concern due to invasive weeds on part of the cay.

Unvegetated cays are dynamic. Seasonal variations in physical dimensions due to wind and wave action are common. These natural variations should be taken into consideration when comparing Health Check data over time. The establishment of vegetation and activity of breeding seabirds is dependent on sufficient cay stability. Seabirds will take advantage of a site for breeding if conditions are suitable for long enough.

The full record of Health Checks, GPS data and photos will be provided to PAD.

Introduced pests

Rodents

Rodent detection surveys were conducted at each of the vegetated cays. No rats or mice were detected.

Ants and invertebrates

Vegetated cays were the focus of intensive invertebrate surveys. General ground searches were conducted on non-vegetated cays.

Seven ant species were collected across five of the seven vegetated cays.

- Cato Island: *Pheidole megacephala* (introduced and invasive)
- Porpoise Cay: No ants collected
- Bird Islet: *Monomorium pharaonis* (introduced), *Cardiocondyla nuda/atalanta*
- East Diamond Islet: *Tetramorium simillimum* (introduced), *Cardiocondyla nuda/atalanta, Nylanderia obscura*
- North East Cay (Herald): *Tetramorium bicarinatum* (introduced)
- North Cay (Willis): No ants collected
- Mid Islet (Willis): *Tetramorium lanuginosum* (introduced), *Cardiocondyla nuda/atalanta*

Of the species identified, the presence of *Pheidole megacephala* on Cato Island is concerning due to their assumed threat to the biodiversity of invertebrate fauna, and therefore potential disruption to normal ecosystem processes.

Other non-ant invertebrates collected and identified through the voyage are deemed natural to the cays and not considered harmful to ecosystems.

Some specimens were only identified to Order or Family. Results of other invertebrates are tabled in the relevant cay summaries.

Drone operations

New high resolution, georeferenced imagery was acquired for 16 cays. Of these, 13 were in the southern reef system and three in the central reef system. All imagery will be provided to PAD.

An attempt to map the missing portion of East Diamond Islet was abandoned due to frigatebirds and their spirited investigations of the drone. East Diamond Islet, North East Cay (Herald Cays) and South West Cay (Herald Cays) were not remapped as these were short, opportunistic visits.

Marine debris

All marine debris information is provided as an attachment in *Appendix 11.*

Recommendations

Recommendations in Hemson et al., 2020 and Chapman et al., 2022 are relevant to the cays assessed on this voyage.

Vegetation

- Eradicate weeds on Bird Islet if possible. This will require regular follow-up until the seedbank has been eliminated and may not be logistically feasible. Refer to the "recommendations for weed management" in the Floristic data section of the Cay summaries Section for Bird Islet, Wreck Reef.
- Additional biosecurity measures (including no unauthorized access) should be put in place to reduce the risk of transfer of weeds from Bird Islet to other cays.
- Revisit Cato Island during a future voyage to obtain vegetation data in locations not able to be surveyed due to the extreme weather conditions during the 2022 voyage and to confirm no weeds were present in these locations.
- Relocate the BioCondition monitoring site (M210 on Mid Islet (Willis Islets) to fit the full 500 m^2 standard site area within the *Argusia argentea* shrubland. This has been scheduled to be done during the 2023 voyage.

Recommendations for future vegetation assessment and monitoring

Three tools are recommended for assessment of the vegetation on the Coral Sea Cays.

1. Vegetation mapping (Neldner et al. 2019): Vegetation maps are foundational 'tools' for land management and ecological assessment. Periodic vegetation mapping is a means for monitoring change in the extent, spatial distribution and floristic composition of vegetation communities over time. Vegetation mapping should be undertaken during initial ecological assessment and repeated periodically to provide this information.

   Vegetation mapping is, however, resource and time intensive and has to be done by a suitably experienced qualified botanist. The tree and shrub layers of the forest and shrubland communities on the cays are not likely to change rapidly so frequent repeat vegetation mapping in these communities is not required. Vegetation of herblands and grasslands and ground layer vegetation in the tree and shrub dominated communities is characteristically resilient and dynamic with relative species dominance and species distribution changing quickly with changes in prevailing climatic conditions and season. These cyclic dynamic changes are generally not important in terms of the habitat provided by this type of vegetation and therefore there is no need to undertake frequent vegetation mapping to document these changes.

   It is recommended that vegetation mapping be repeated at intervals of approximately 10 years unless there is a need for more frequent assessment following recovery from major vegetation disturbances e.g. cyclones.

2. Health Checks (Melzer, 2019): Health Checks are likely to be adequate for more frequent monitoring of the condition of the range of ecosystems and vegetation communities on the cays. Health Checks are qualitative tools for efficiently and routinely monitoring the condition of key values using use simple visual clues and are based on assessment of threatening processes and their impacts (e.g., infestations of pest plants, trampling, cyclone impacts, dieback), or particular parameters (e.g., faunal habitat features, ground cover, recruitment of canopy species), that are good indications of condition. Assessors require only basic training in the method and concepts and do not require qualifications or experience in scientific methods and no special scientific equipment is required.

It is recommended that heath checks be done on each cay visited on every voyage, with a minimum interval of two years if possible. Highest priority communities for Heath Checks are *Pisonia grandis* (pisonia) forests and *Cordia subcordata* (sea trumpet) communities.

Health checks should be repeated in the same locations where they were done previously. Once vegetation mapping is available, additional sites may need to be added to future surveys to ensure all important vegetation community types are included.

3. BioCondition monitoring (Eyre et al., 2015; Eyre et al., 2017): Permanent monitoring site locations are selected for each vegetation community in representative areas in good BioCondition ("Reference State") at replicate locations within the Coral Sea Marine Park. Initial monitoring of these sites provides BioCondition benchmarks for each of the vegetation communities. BioCondition scores in the same communities in revegetation sites or other Coral Sea locations are calculated by comparing attributes recorded with benchmarks for each of the attributes. Regular monitoring of these sites will also provide information on vegetation changes in these communities over time and under different climatic conditions. A qualified botanist and a recorder are required and monitoring of each site takes between half an hour for grassland/herbland sites to 45 minutes for a simple shrubland site to 2 hours for a forest community with large trees.

   It is recommended that monitoring is repeated once every 10 years with the repeat vegetation mapping surveys. If Health Checks detect changes of any concern, BioCondition monitoring should be repeated as soon as possible.

Vegetation mapping and monitoring, particularly quantitative monitoring requiring intensive assessment of individual sites, should be undertaken outside of the breeding season for wedge-tailed shearwaters because of the significant risk of collapsing active burrows. It is recommended that these surveys be undertaken in early to mid-June while the ground layer vegetation is still in good condition following the summer rains and wedge tailed shearwater chicks are no longer present.

Soils

Once all vegetated cays have been surveyed, the available soils data should be reviewed by a soil scientist to:

- Interpret all the data.
- Explain the causes and potential consequences (if any) of the elevated levels of iron, aluminium, manganese, copper, zinc and possibly calcium in the soil samples from the grey water outlet (and other sites) on South Islet (Willis islets).

Birds

Birds are a conspicuous value of marine and terrestrial ecosystems of the Coral Sea. They are an aesthetic value as well as playing a critical role in floristic and physical ecosystem functions of cays. The following recommendations are provided for ongoing management of birds and their habitats.

Continue gathering seasonal, baseline bird data for all cays. Comprehensive baseline information may take years to ensure seasonal variations, species diversity and habitat requirements are fully understood.

- Continue ground-based counts complemented with drone imagery. Flight heights should be 40m to 50m to allow for higher resolution images. This will benefit bird and vegetation monitoring. Trip planning will need to consider the extra field time required when obtaining higher resolution imagery.

- Minimise movement by researchers through vegetated cays when vegetation is abundant and lush, and species such as sooty terns and brown noddies are nesting or have mobile chicks and young. Some carefully planned movement inside cays will be required by the bird researcher to determine species and abundance, and to extrapolate data if required. Transect based monitoring in some instances will cause too much disturbance to seabirds and provide inaccurate data due to mobile chicks and young vacating the transect parameters.
- Consider mainland-launched, fixed wing drone footage to sample breeding effort by species such as New Caledonian fairy terns on known and potential breeding areas, particularly if scheduled boat-based voyages fall outside the expected breeding times of late June, early July.
- Always engage research staff with specific expertise in the detection and identification of all bird species. Seabirds are the main interest group, but important information for shorebirds and other island birds is required to collect comprehensive voyage data.
- Encourage all voyage participants to take photographs when possible. The diversity lists for two cays were improved by extra species being identified via general photos.
- Alert other researchers to no-go areas. These are to protect easily overlooked species with camouflaged eggs and chicks.

Once sufficient data are collected across the CSMP, a workshop to determine priority species, locations, ongoing monitoring and future management should be convened. Collated data should include a literature search of all previous surveys.

- Assess identified threats and determine actions required to maintain habitats. An action could be “no action required”. An outcome of this process should be designating no access or restricted access zones to the public. These could either be permanent or seasonal.

Other targeted research opportunities:

- Catalogue the presence and diversity of pelagic seabirds along the chain of seamounts from the Fraser Guyot to the Mellish plateau.
- Mark/recapture and/or satellite tracking studies on red-tailed tropicbirds in the Herald Cays group. Survey results from this voyage produced data on a previously unknown population of breeding adults. Similar research on other species may be relevant.
- Workshop potential research opportunities identifying foraging areas for species and understanding population interactions between the CSMP and adjoining marine areas.
- Targeted research may be considered for Herald petrels and New Caledonian fairy terns considering their extremely low populations in Australia, and globally, respectively.

Other (general):

- Continue improving monitoring methodologies and techniques. Data collection needs to be robust, repeatable, and cause minimal disturbance to species. Once a baseline understanding of bird values is known, several key sites, representative of general sites, may warrant focused monitoring.
- Document data through formal reports and scientific papers. Share relevant data with bird organisations and interest groups.
- Collate an audio and photographic library of all species and their habitats.
- Ensure biosecurity requirements are outlined and followed by researchers and guidelines are promoted to other visitors.

Values assessments - Key values (adapted from Chapman et al. 2022)

We recommend Values Assessments (VA) are undertaken for the cays of the central and southern reef systems. The Values Assessment process selects and defines the key values - those values that are most significant to individual protected areas. The values assessment also prioritises values, risks and management responses, and informs decisions around where monitoring is vital for management, useful or a low priority.

For the vegetated cays the detailed assessment work undertaken during the May/June 2022 voyage will inform the values assessments together with past research undertaken on similar cay environments in the CSMP. However, there appears to be limited studies of the unvegetated cays of the CSMP. Excluding the intertidal cays, the unvegetated cays (with evidence of seabird breeding) visited during May/June 2022 ranged in size from approx. 76 m^2 to 4.12ha above high water. As well as providing suitable seabird nesting habitat, many provided turtle nesting habitat. It is documented that the two largest unvegetated cays in the Great Barrier Reef region are 4.1 ha (Sandbank No. 7) and 2.7 ha (Waterwitch Cay). All remaining unvegetated cays in the region are <1.6 ha (Hopley et al., 2007). Given the number, size and habitat values of the unvegetated cays in the central and southern reef systems a study into their geomorphology would provide a better understanding of cay dynamics and stability particularly with the impacts of climate change. This knowledge will inform the value of these cays and guide future management.

Additional Health Checks should be conducted in any vegetation communities missed during the May/June 2022 voyage.

Island Watch (from Chapman et al. 2022)

The Island Watch tool was developed by QPWS&P as an early warning system for pest incursions (biosecurity surveillance) and the detection of other threats or changes to natural values, so that early management intervention can be undertaken. An Island Watch survey should be completed for each island visited during a trip.

Introduced pests (from Chapman et al. 2022)

Pest invertebrates

Autumn is the preferred season to survey invertebrates and detect weeds on the CSMP cays. Invertebrates with the potential to impact on the key vegetation communities on the cays in the CSMP would be most abundant following the growth flushes induced by the summer wet season.

Invasive ants

Consideration should be given to assessing the feasibility and likely benefits of eradicating exotic ant species. These exotic species have known, albeit varied impacts on native Australian wildlife and may cause significant impact to native ecosystems on remote cays such as those in the CSMP.

Drone operations

The following points are recommendations for future drone operations:

- Where no geo-spatial imagery is available to create flight boundaries (as KML files), creating flight plans while on site and flying the drone to lay a track proves very effective.
- Map/flight boundaries should be square, or rectangular, aligned north-south and east-west. Some cays are aligned northwest to southeast or northeast to southwest. Mapping on these alignments can result in “untidy” flight captures. For reporting and display purposes full rectangular or square captures are ideal.
- Ensure a backup drone and associated accessories are available for each voyage.

- Drone flight heights are determined by the product required. General mapping, including basic vegetation mapping can be achieved at higher altitudes while more detailed vegetation boundary comparisons and seabird monitoring should be flown at lower altitudes such as 40m.

Drone imagery provides an efficient and repeatable means to monitor cay movement, changes in island profile and area, gross changes in vegetation structure and composition, and available habitat for seabird and turtle breeding. The imagery is also highly valuable for bird counts and for informing ground truthing for vegetation mapping.

Consideration should be given to procuring a differential GPS and set of ground control point markers to improve spatial precision of resulting maps. Spatial precision commensurate with the very high resolution of the maps would enable detailed assessments of beach volumes, vegetation shifts and other changes.

Visitation and biosecurity (based on Chapman et al. 2022)

Visitation frequency by free and independent travelers is low and probably concentrated to a handful of sites with sufficient anchorages.

Low visitation rates by themselves are not sufficient to ensure the values of the CSMP cays are protected. Biosecurity concerns and threats to seabird breeding events should be managed to ensure ongoing health and maintenance of island values.

Many sites will be self-protected due to difficulties of access by vessel, weather conditions and lack of interest by perceived aesthetic values of a site.

Formulating standard operating procedures and zoning via a series of workshops for each cay are recommended. The workshops should consider:

- Specific island values and their protection needs (vegetation, disturbance levels to seabird species, biosecurity considerations, fire threats).
- Access to a cay or cays representing an example of overall values for the enjoyment of free and independent travellers.
- Access safety – prohibiting access to those areas deemed as generally unsafe (currents, reef structure, swells).
- No access cays (apart from approved research) for the protection of sensitive species e.g., New Caledonian fairy tern, and to reduce the risk of week spread e.g., from Bird Islet to other cays.

It is recommended that all camping (recreational, commercial, educational and scientific), be prohibited in the CSMP to minimise biosecurity risks. Equipment campers typically use provides significant opportunities for invasive species to ‘stow away’ and be introduced to the natural ecosystems of the CSMP. Camping is unnecessary given that all vessels will need to have overnight accommodation in order to legally transport visitors to the CSMP from Australian mainland ports.

It is further recommended that day visitors, for recreational and commercial purposes, be restricted to the beaches and not be permitted to take equipment (e.g. tables, chairs) ashore. Shade structures, water containers, first aid gear and other equipment that could be considered necessary from a health and safety perspective should not be taken above the highest tidemark. Ideally all such equipment should be brand new at the start of trips from the mainland or otherwise very thoroughly cleaned. All equipment must be inspected and sprayed (e.g. crawling insect surface spray) before going ashore and between each island. Multilayered containers and structures made from materials such as corflute should not be taken aboard vessels nor ashore.

No fresh food, including cooked or uncooked meats, breads, fruit and vegetables should be taken ashore. The timing and average length of stay on an island should be such that only drinking water and pre-packaged snacks (e.g. muesli bars, dried fruits, sweets etc.) are needed.

Authorised researchers on the CSMP islands should adhere to similar protocols outlined for recreational and commercial visitors regarding food and equipment. Researchers will require further protocols when working above high tide levels and between cays. For example, when moving between cays they must ensure their field equipment and boots are thoroughly cleaned in VirkonS® or similar. Wearing clean clothes washed in detergent and water at >40°C for each new cay and washing and inspecting hats and backpacks will also reduce the chances of transporting pests between cays.

Signs and building materials including site and transect markers and other installations must be new and sourced from authorised/guaranteed clean suppliers. Immediately prior to installation, such material must be thoroughly cleaned and inspected before deployment and again before being redeployed or repurposed.

It is recommended that a study be commissioned to identify the most significant biosecurity risks to cay values, along with their likely sources, vectors and pathways of introduction.

Introduction (John Prichard)

The Coral Sea Marine Park (CSMP) is located east of the Great Barrier Reef Marine Park (*Figure 1*). It extends from Cape York Peninsula to just north of Bundaberg in Queensland, Australia. There are approximately 34 vast reef areas and 67 cays and islets in the CSMP including the Coringa-Herald and Lihou Reefs and Cays Ramsar site. The Ramsar site comprises near-pristine oceanic islet and reef habitats that are representative of the Coral Sea. The undisturbed sandy habitats at several islets are nesting sites for globally threatened marine turtles, while the foreshores and vegetation support important breeding populations of seabirds (Director of National Parks, 2018).

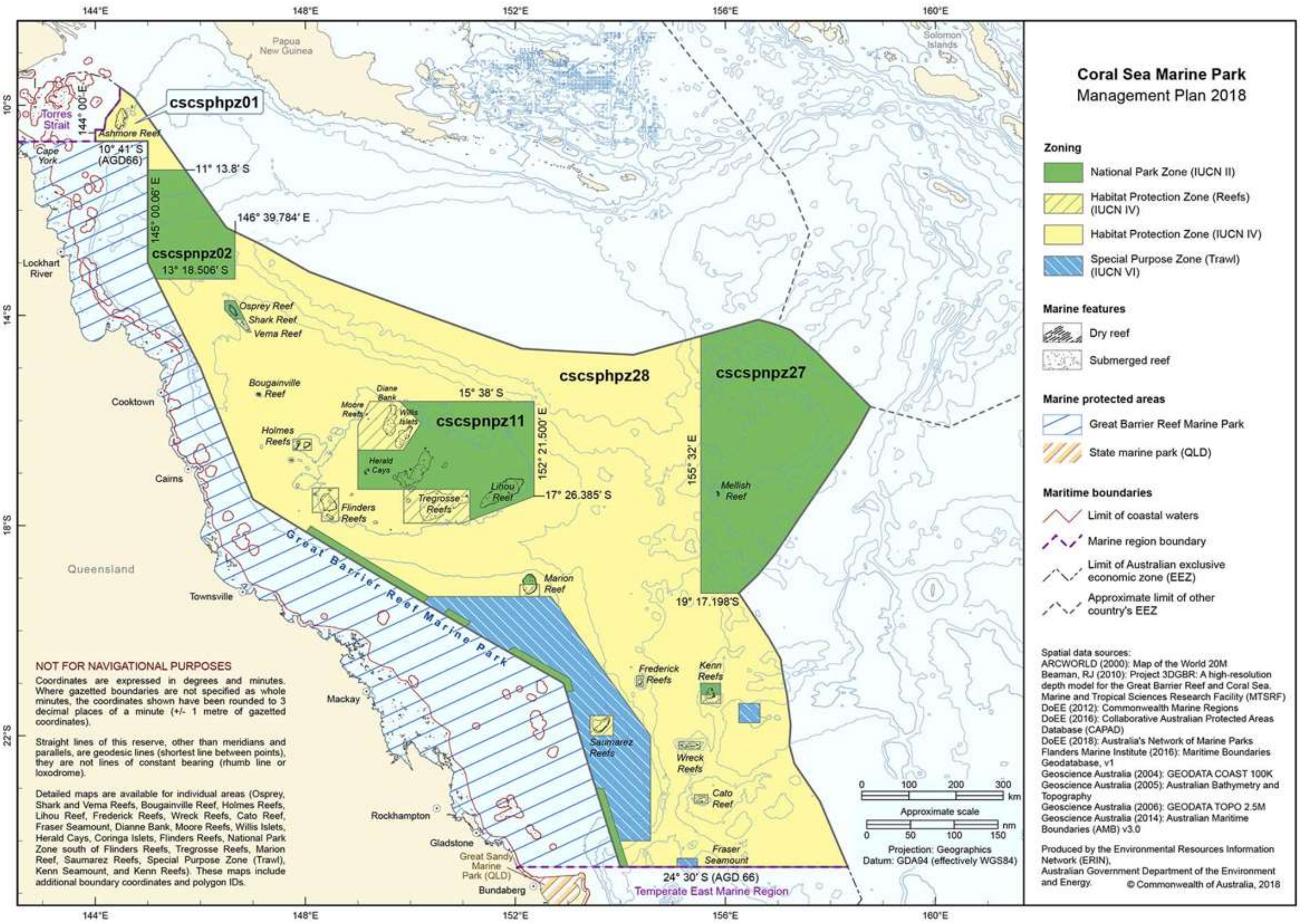

Figure 1 Coral Sea Marine Park {from CSMP Management Plan, Director of National Parks (2018)} indicating location of Island Health Monitoring

Parks Australia Division (PAD) manages the CSMP under the *Coral Sea Marine Park Management Plan 2018.* PAD and the Great Barrier Reef Marine Park Authority (GBRMPA) have a Memorandum of Understanding (MOU) to enable management efficiencies between the two marine parks. As part of this MOU, the GBRMPA Reef Joint Field Management Program (RJFMP) has been assisting PAD with the delivery of field management activities in the CSMP, such as monitoring and managing island and cay species and habitats.

A collaborative trip to six islands in the Coringa-Herald section of the CSMP was undertaken between 28 November and 11 December 2019. During that 13-day voyage a team of experts from PAD and the Queensland Department of Environment and Science (DES), Queensland Parks and Wildlife Service and Partnerships (QPWS&P) piloted methods to collect, analyse and document the health status of terrestrial island ecosystems and species using the islands, to establish baseline data for future trend analysis. The results and discussion have been published in Hemson et al. 2020.

The success of the 2019 voyage and the subsequent *Environmental Assessment Report* proved the methodology is appropriate for the island health assessment in the CSMP.

This same assessment was undertaken for the July 2021 CSMP Island Health Voyage, which visited four vegetated Diamond Islets in the far east section of the Tregrosse Reefs and 21 cays and islets in Lihou Reef, five of which are vegetated and 16 are unvegetated sandy cays. *Figure 1* indicates the location of Tregrosse Reefs and Lihou Reef, and *Figure 2* provides a larger scale map of the Tregrosse Reefs and Lihou Reef cays and islets visited, which included: West Diamond Islet, Central Diamond Islet, East Diamond Islet and South Diamond Islet (all in the Tregrosse Reefs), and South West Cay, Georgina Cay, Helen Cay, Edna Cay, Fanny Cay, Dianna Cay, Phoenix Cay, Carol Cay, Betty Cay, Hermit Crab Islet, Frankie Cay, Observatory Cay, Middle Cay, Turtle Islet, Margaret Cay, Little Margaret Cay, Lorna Cay, Kathy Cay, Juliette Cay and two small unnamed cays.

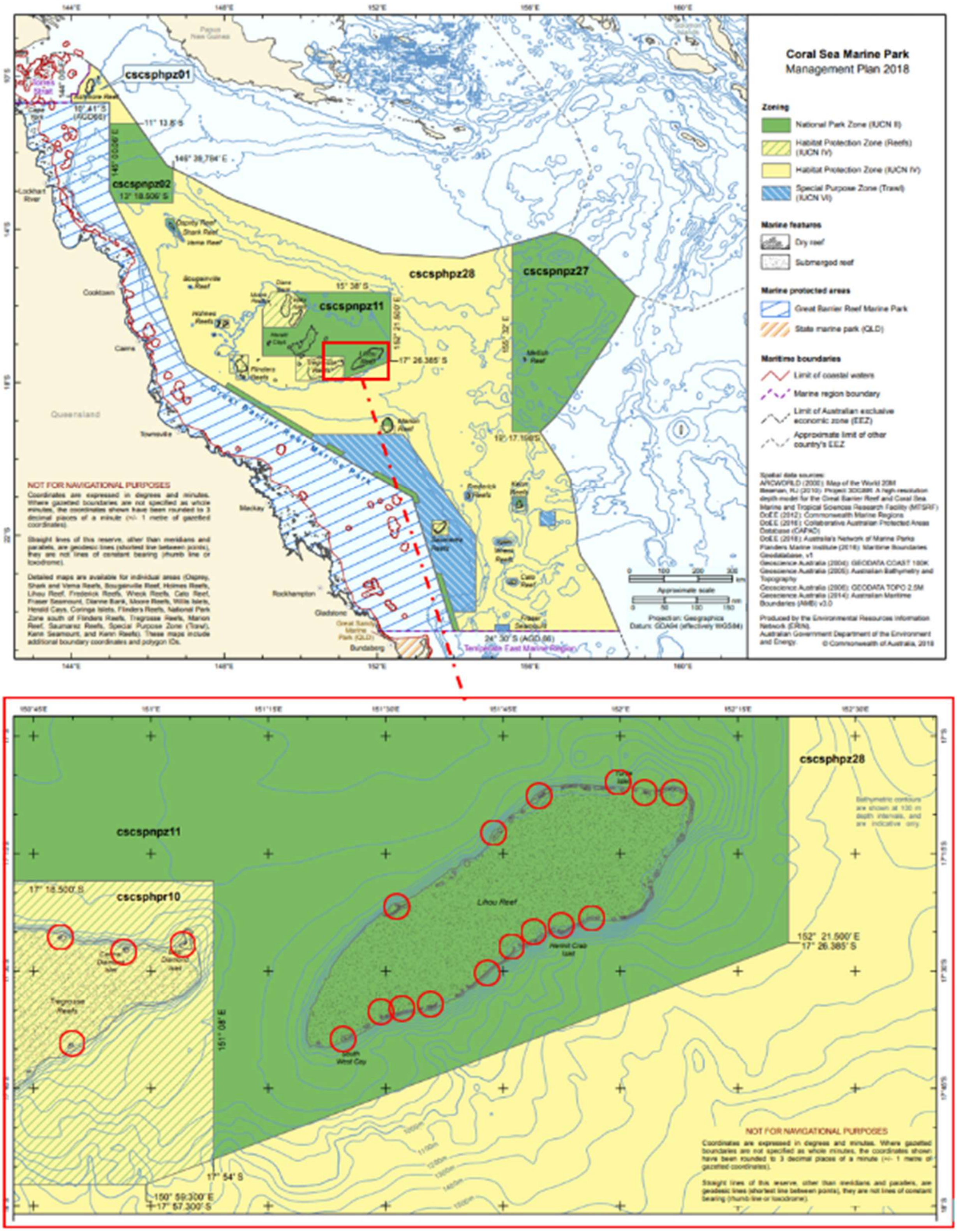

Figure 2 Tregrosse Reefs (Diamond Islets) and Lihou Reef {from CSMP Management Plan, Director of National Parks (2018)} indicating approximate track of voyage to conduct island health assessments of cays and islets

The results and discussion of the July 2021 voyage have been published in Chapman et al. 2022*, Environmental Assessment of islets and cays of Tregrosse and Lihou Reefs, Coral Sea Marine Park, July 2021.* In addition to the island health assessments, deep reef coral research was undertaken during the voyage by James Cook University researchers utilising a remote operated vehicle (ROV), and the cays and islets were cleaned of all marine debris, which was removed and brought back to the mainland for assessment. Reports of both these activities are included in the 2022 report.

A third CSMP Island Health Voyage was undertaken between 22 May to 09 June 2022 covering 20 cays and islets situated through the southern and central regions of the CSMP (see *Figure 3*). Of the 20 islands visited, 7 were vegetated. PAD and DES QPWS staff were involved again, plus a member of the Tangaroa Blue Foundation (TBF), a not-for-profit organisation involved in the removal, analysis and recording of marine debris since 2004.

The results of the island health assessments are detailed in this report, along with the analysis and report on the marine debris collected and returned to Australia.

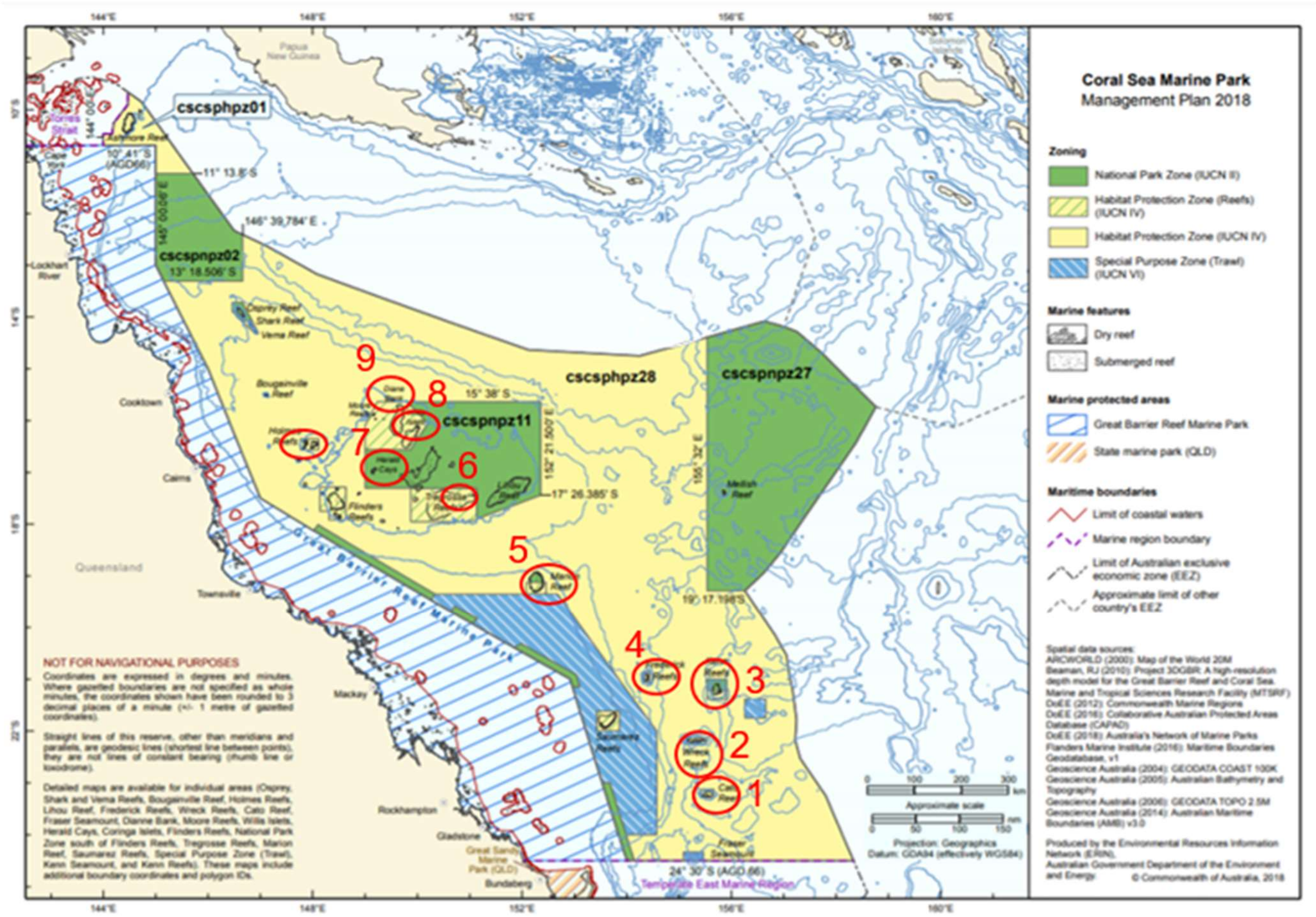

Figure 3 Assorted central and southern cays and islets of the CSMP (CSMP Management Plan, Director of National Parks, 2018). 1. Cato Reef, 2. Wreck Reefs, 3. Kenn Reefs, 4. Frederick Reefs, 5. Marion Reefs, 6. East Diamond Islet (Tregrosse Reefs), 7. Herald Cays, 8. Willis Islets, 9. Diane Bank

Part I: Methodologies, general results and discussion

1.1 Vegetation and soils - Joy Brushe and Larry Brushe

1.1.1 Methodology

Field Surveys

Between 25 May and 07 June, 2022, 21 cays were visited. Of these, five were vegetated and 16 were confirmed to be unvegetated. Two people each spent approximately 27 hours in the field (between 1.3 and 7.6 hours per cay) surveying the vegetation on the five vegetated cays. This included establishing and surveying six permanent BioCondition monitoring sites. Data was recorded in a total of 109 ground-truthing sites. The number of sites per cay ranged from 10 on Porpoise Cay to 32 on North Cay (Willis Islets). The locations of these sites are shown on maps of each of the islands in the Cay Summaries.

In addition, opportunistic visits were made to three additional cays, East Diamond Islet, North East Herald Cay and South West Herald Cay. with a total of 4, 6.5 and 2 hours respectively inspecting the vegetation on these cays.

In July 2021 an *Argusia argentea* (octopus bush) shrubland permanent monitoring site (M06) was established on East Daimond Islet. Large numbers of nesting red-footed booby (*Sula sula*) and frigatebirds (*Fregata spp.)* in the branches of the *Argusia* shrubs prevented access to most of the site, so the survey could only be partially completed in 2021. Although some nesting birds were present in the 2022 visit, the site survey was able to be completed, with the exception of an accurate shrub count due to limited access to parts of the site. On North East Herald Cay, the *Cordia subcordata* (sea trumpet) patches suffering from severe dieback during the December 2019 survey were revisited. Three ground truthing sites were surveyed in these patches and four plant specimens collected. The remaining time on the three cays was spent searching for weeds as thoroughly as possible in the time available.

Ground truthing sites

Prior to the field trip, spatially rectified recent satellite images with 30 to 50 cm pixel resolution supplied by PAD were used to identify visually distinguishable patterns of vegetation on each cay using the QGIS program. Point coordinates of suitable locations for ground-truthing of these patterns were created using QGIS and uploaded to a Garmin GPSMAP 66S hand-held GPS. Spatially rectified PDF maps of the delineated image patterns overlain with these coordinates were generated in QGIS and loaded onto the Avenza maps program on iPhones to accurately locate the ground-truthing sites while traversing the cays. Data was recorded in the vicinity of these locations and at other locations chosen during the field trip.

As time on each cay was limited, it was not possible to undertake comprehensive replicate site surveys in each vegetation community using the standard methodology of Neldner et al. (2019). To ensure sufficient data was obtained and the vegetation of the entire island was thoroughly assessed, a modified “quick” methodology was used with the following data recorded at each of the ground truthing sites:

- GPS coordinates
- Vegetation structure (from estimated height and cover)
- All plant species present
- Cover of each species and litter at the site
- Total weed cover
- Landform
- Aspect (if applicable)
- Estimated altitude
- Surface soil description
- Observations of seabirds and evidence of marine turtle activity
- Site photographs.

The number of square metres included in each site was not defined. The data recorded at each of the sites represented an area surrounding the recorded GPS coordinates that was homogeneous in terms of vegetation, soil, slope and aspect.

Average time taken to complete each of these sites was 6.4 minutes (11.7 minutes including traversing time).

The site data recorded was used to:

- Identify and describe all the vegetation communities present on each cay and the variation within each community.
- Obtain a complete floristic inventory for each cay.
- Identify the spatial extent and abundance of weed species if these were present.
- Attribute vegetation patterns on the drone imagery to create vegetation maps.
- Note habitat preferences of seabirds and turtles.
- Assess potential human impact on vegetation.
- Document evidence of pests, diseases or any other threats to the vegetation.

Heights and covers of vegetation at each site were estimated to derive the structure class of the vegetation at each site as described in Neldner et al. (2019). Refer to *Appendix 4.*

The cover of each species at each site was recorded as one of the following cover classes as described by Daubenmire (1959):

- trace to 5%
- 6% to 25%
- 26% to 50 %
- 51% to 75%
- 75% to 95 %
- 95% to 100.

This method provided a simple rapid method to document the relative dominance of each species at each site and obtain structural information required to describe the vegetation communities. The midpoints of each of these cover classes were used to obtain average % covers and for comparison with previous data.

Surface profiles

Surface profiles showing relative elevation were generated for each of the vegetated cays from the drone image capture using Drone Deploy. It was not possible to determine actual elevation as no vertical datum was available.

Vegetation mapping

Following the voyage, vegetation maps were created in QGIS by delineating polygon boundaries around patterns distinguishable on the high-resolution orthorectified drone image mosaics generated in Drone Deploy from the drone images captured during the 2022 voyage. Vegetation communities identified from the ground truthing site data were assigned to each polygon. Each polygon was allocated a reliability A, B or C for both line placement and allocated vegetation type (A= confident, C= low confidence). Where patchy mosaics containing more than one vegetation type were present, the vegetation was mapped in heterogeneous polygons, each containing up to three vegetation communities with an estimate of the percentage of each vegetation community within the polygon. The line reliability, vegetation reliability and percentages of the component vegetation types for each polygon cannot be shown in the vegetation maps in this report as this would create too much visual detail. These attributes are contained in the DBF component of the ESRI shapefiles provided to PAD.

BioCondition monitoring sites

When allocated time on the island permitted, permanent BioCondition monitoring sites located in representative areas within a range of vegetation communities were established.

Six permanent monitoring sites were established and surveyed on the cays during the 2022 voyage, two on Cato Island, two on Bird Islet, and one each on North Cay (Willis Islets) and Mid Islet (Willis Islets).

The purpose of these BioCondition monitoring sites is to:

- Provide benchmark reference data for BioCondition* assessment for the same vegetation communities elsewhere on other Coral Sea cays.
- Document changes in vegetation over time.
- Assess the impact of climate change and other disturbances on vegetation.

*BioCondition is a site-based, quantitative, and repeatable, condition assessment methodology that provides a measure (expressed as a BioCondition score between 0 and maximum of 1 and BioCondition Class of 1, 2, 3 or 4 – one being the best) of how well a terrestrial ecosystem is functioning for biodiversity values. A suite of attributes (e.g., canopy cover, coarse woody debris, native plant species richness, litter cover) are assessed at a site and evaluated against benchmarks for those attributes. The benchmarks for attributes are derived from *a reference state* for the ecosystem – the latter being the natural variability in attributes of an ecosystem relatively unmodified since the time of European settlement (Eyre et al. 2015).

BioCondition benchmarks are obtained by averaging survey data for each vegetation attribute from replicate benchmark reference sites located in pristine representative locations within each vegetation community within the Coral Sea Marine Park. It is also desirable to include benchmark data obtained at different seasons to capture seasonal variation in the benchmarks. The survey data from the six BioCondition reference sites established on the 2022 voyage, the 11 sites on the Diamond Islets and Lihou Reef cays established on the July 2021 voyage, the three *Pisonia grandis* (pisonia) reference sites surveyed in December 2019 (Hemson et al. (2020) and data from reference sites established and surveyed during the 2023 Voyage will be used to determine benchmarks for future BioCondition assessments.

Sites were permanently marked with galvanised star pickets located at the 0m and 50m ends of the 50m centre transect (0m and 30m on M21 on Mid Willis Islet) of the 50m x 10m sites and labelled with PAD engraved identification tags made of 316 grade stainless steel firmly attached with two stainless steel cable ties to prevent movement in strong winds as shown in *Photo 1a & b*. To minimise visual impact, posts were driven deeply into the ground to an above ground height of approximately 0.7 metre.

Photo 1a and 1b: Permanent sites were marked using star pickets labelled with Parks Australia stainless steel identification tags. Joy Brushe ©

The secondary site survey methodology of Neldner et al. (2019) with some slight modifications to accommodate cay vegetation was used. Time taken to complete surveying of these sites varied from 20 minutes (a rushed site on Mid Islet (Willis Islets)) to 55 minutes. The methodology used is described in *Appendix 4* and Neldner et al. (2019).

To ensure long term secure data storage and accessibility, data and photographs recorded at the permanent monitoring sites will be stored digitally by PAD and also by the Queensland Herbarium in the QBEIS database.

Soil analyses

Soil samples were collected from depths of 0-10cm, 10-20cm and 20-30 cm in each of the permanent monitoring sites for analysis. A sand auger was used where possible. Where the sand was dry and could not be picked up with the auger, samples were collected using a post hole shovel with the assistance of a small hand shovel. Samples were not collected at greater depth due to both difficulty of obtaining the samples and time restrictions.

Samples were analysed at the analytical laboratories at the University of Queensland School of Agriculture and Food Sciences. The following previous cay soil samples were also analysed by this facility using the same/compatible methodology, providing opportunity for valid comparison of their analyses with those of samples collected during the 2022 voyage:

- 33 soil samples collected from the BioCondition monitoring sites on the Diamond Islets and Lihou Reef cays during the July 2021 voyage.
- Samples collected by George Batianoff et al. in October 2007 of 50 soil profiles from cays in the Coringa-Herald National Nature Reserve.
- 213 soil samples collected from the Capricornia Cays by Batianoff et al. during 2007/2008.

Nine soil samples collected by Joy Brushe from South Islet (Willis Islets) in October 2020 were analysed by SGS Cairns International who advised that compatible methodologies were used to ensure valid comparison with the University of Queensland data sets.

The soils samples were analysed for: pH, electrical conductivity, total nitrogen, total carbon, total organic carbon, available phosphorus, calcium, potassium, magnesium, sodium, cation exchange capacity, total phosphorus, aluminium, calcium, copper, iron, potassium, manganese, sodium, sulphur and zinc.

Analysis of particle sizes and Munsell colour were not done.

Plant and drift seed collections

Specimens of each plant species present on each cay were collected. These plant specimens were labelled, pressed and dried and field notes recorded on the habit and habitat of each. The specimens together with recorded information have been sent to the Queensland Herbarium in Brisbane and the National Herbarium in Canberra as confirmation of the presence of the species in the locations recorded in this report. Specimens collected on the Willis islets, East Diamond and the Herald Cays were also sent to the Australian Tropical Herbarium in Cairns.

The difficulties experienced on the July 2021 voyage in drying salty specimens on board the boat in the humid ocean environment were significantly reduced on the 2022 voyage by placing the plant press containing the specimens in a sunny location inside a lightweight black compost bin (shown in *Photo 2)*. The bin had holes at the base and additional holes were drilled at the top to facilitate airflow through the specimens. The bin was secured on deck using ropes threaded though cleats fitted to the bin.

Photo 2 Compost bin used to dry plant specimens
Joy Brushe ©

Where time permitted, and with the assistance of other members of the team, samples of drift seeds were collected opportunistically from the shorelines of both vegetated and unvegetated cays. The purpose of these collections was to obtain knowledge of the plant species arriving on these cays via ocean currents. Plant and drift seed specimens were collected with the permission of The Director, PAD.

Botanical nomenclature

Scientific plant species names used in this report are according to the Census of the Queensland Flora 2021 (Brown, 2021). Common names are included in brackets following the first use of each scientific name in the document and in some descriptive sections.

Additional digital data

In addition to this report, the following files were supplied separately to PAD:

- An ESRI shapefile of the vegetation mapping. The database file associated with this shapefile contains additional information including the area of each polygon, the percentage of each vegetation map unit within each of the heterogeneous polygons, the reliability of the location of the polygon boundaries (a, b, c) and the reliability of the allocated vegetation unit (a, b, c).
- An excel file of the vegetation map legends.
- An ESRI shapefile and a Microsoft Excel file of all the data recorded at each of the ground truthing sites.
- All photographs taken at the ground-truthing sites.
- ESRI shapefiles containing the locations and GPS coordinates of the BioCondition monitoring sites.
- An excel file of the BioCondition monitoring site data.
- All photographs taken at the BioCondition monitoring sites.

1.1.2 General results and discussion

Limitations of the vegetation survey, mapping and reporting

BioCondition scoring could not be undertaken for the BioCondition monitoring sites surveyed during the July 2021 voyage as benchmarks for vegetation attributes of the vegetation communities at these sites have not yet been determined.

During the voyage, 21 cays were visited, including 16 unvegetated cays in addition to the 5 vegetated cays. To complete all the scheduled work on all these cays and to allow for steaming time between cays, time on each cay had to be limited. Available survey time on each vegetated cay varied between one and a half hours and eight hours. This resulted in insufficient time available on some cays to visit all the ground-truthing sites identified prior to the voyage and limited the number of BioCondition monitoring sites that could be established and surveyed to one or two per cay. Work on Cato Island was difficult and progressed at a slower rate than on other cays due to rainy windy conditions. Planned work for the last afternoon on Cato had to be abandoned altogether due to extreme weather. Time spent surveying each cay and the number of ground-truthing and BioCondition monitoring sites surveyed on each cay are documented in *Appendix 1*.

Comparisons of ground cover data for Cato Island obtained during the 2022 voyage with those reported previously must be interpreted with caution as different methodologies were used for site/quadrat location. The previous survey data was recorded only for a very limited part of the cays and a large part of the cay was not surveyed during the May/June 2022 survey. So average ground covers may not be representative of the entire cay for either of these surveys.

While the information obtained during the 2022 voyage provided good detail on the vegetation present at the time of the surveys, the structure and floristic composition of vegetation communities dominated or co-dominated by annual herbs, other herbaceous species and short-lived shrubs, are likely to be very dynamic, varying between seasons and in response to varying climatic regimes.

Because of the small size of the cays, the low species richness of the flora and the predominance of herbaceous species, some of which have annual growth patterns, many of the communities were quite similar, differing only in the relative dominance of component plant species. This created difficulties when deciding whether small patches of vegetation which differed from surrounding vegetation were distinct communities or whether they were just a variation of the surrounding vegetation community. There was also quite a lot of mosaicking of community types which could not be shown on the vegetation map despite the large scale and high level of detail of the mapping. Where this occurred, heterogeneous polygons containing more than one vegetation type had to be used.

Due to limited time available and the difficulty of collecting samples of dry sand specified depths, soil samples were collected from only the top 30 cm of the soil profile (0-10cm, 10-20cm and 20-30 cm) so no data is available for depths greater than this.

Vegetation condition

At the time of the 2022 surveys, the vegetation was generally in very good condition following a wetter than average autumn. The higher autumn rainfall is shown in the graphs in *Figure 4*. These graphs compare the 2021-2022 monthly rainfall data with long term monthly averages (1921 to 2021) recorded on South Islet (Willis Islets) Bureau of Meteorology (BoM) recording station, (the closest recording station to Mid Islet (Willis Islets) and North Cay (Willis Islets)) and the Gladstone BoM recording station (the closest rainfall recording weather station to Cato Island and the Wreck Reef Cays.

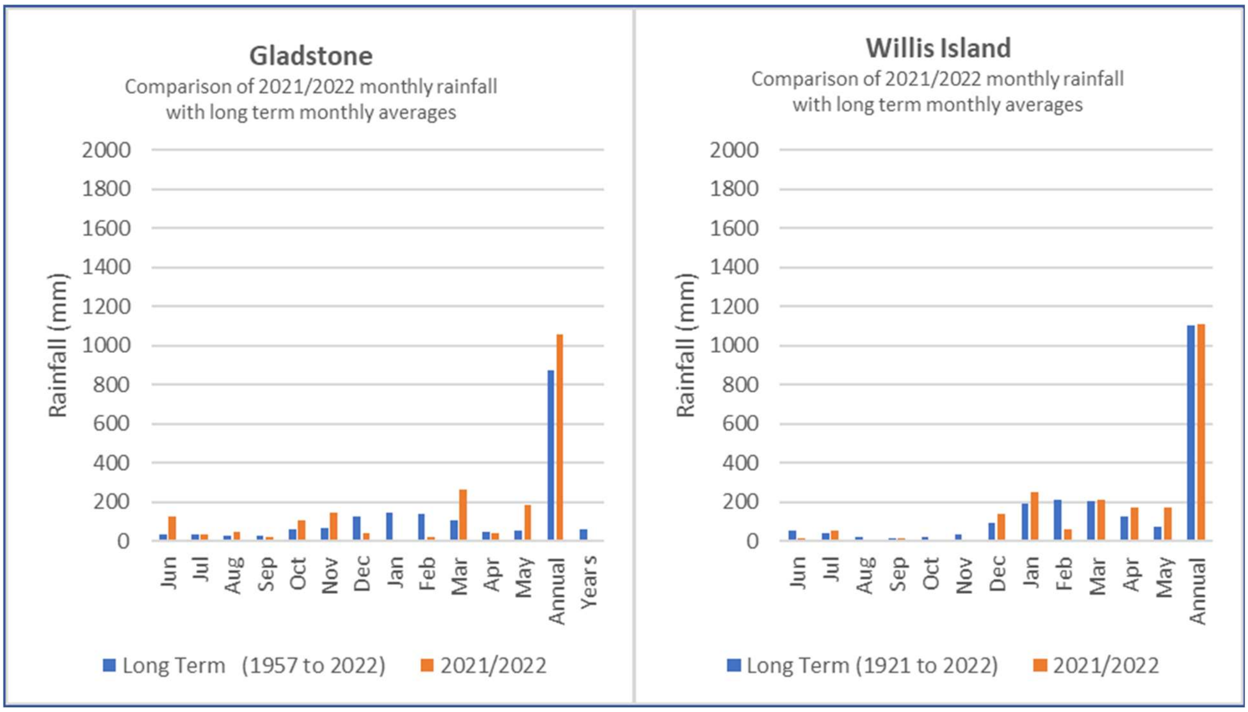

Figure 4 Comparison of recent (June 2021 to May 2022) and long-term monthly rainfall data for Gladstone and South Islet (Willis Islets).
(Australian Bureau of Meteorology website viewed July 2022)

Floristic data

Native cay plant species

Batianoff et al. (2009a) noted that the flora of the northern CSMP is a subset of the widely distributed western Pacific low coral island flora and that a high percentage of low-lying coral island floras are predominantly oceanic or seabird-dispersed littoral species. Predominant dispersal mechanisms of the Coral Sea native species are included in *Appendix 2.*

The predominant oceanic current carrying plant propagules to the Coral Sea cays is the Pacific east to west South Equatorial Current. The South Equatorial Current flows from the Pacific towards the Australian mainland and then bifurcates into the north flowing Hiri Current and the south flowing Eastern Australian Current. Surface currents driven by the South-East Trade winds and seasonal monsoon winds also play a role in plant dispersal. Batianoff et al. also noted that species turnover is a usual event on cays, reflecting the balance between immigration, survival and extinction rates which in turn are influenced by bird, turtle and human activity, climatic regimes and other disturbances.

While species richness on Coral Sea Marine Park cays does seem to be related to total vegetated area to some degree (refer to *Figure 5)*, it is likely that other factors such as disturbance history, maximum elevation of the cay, location in relation to ocean currents and time since vegetation establishment began also influence the number of species currently present on each cay.

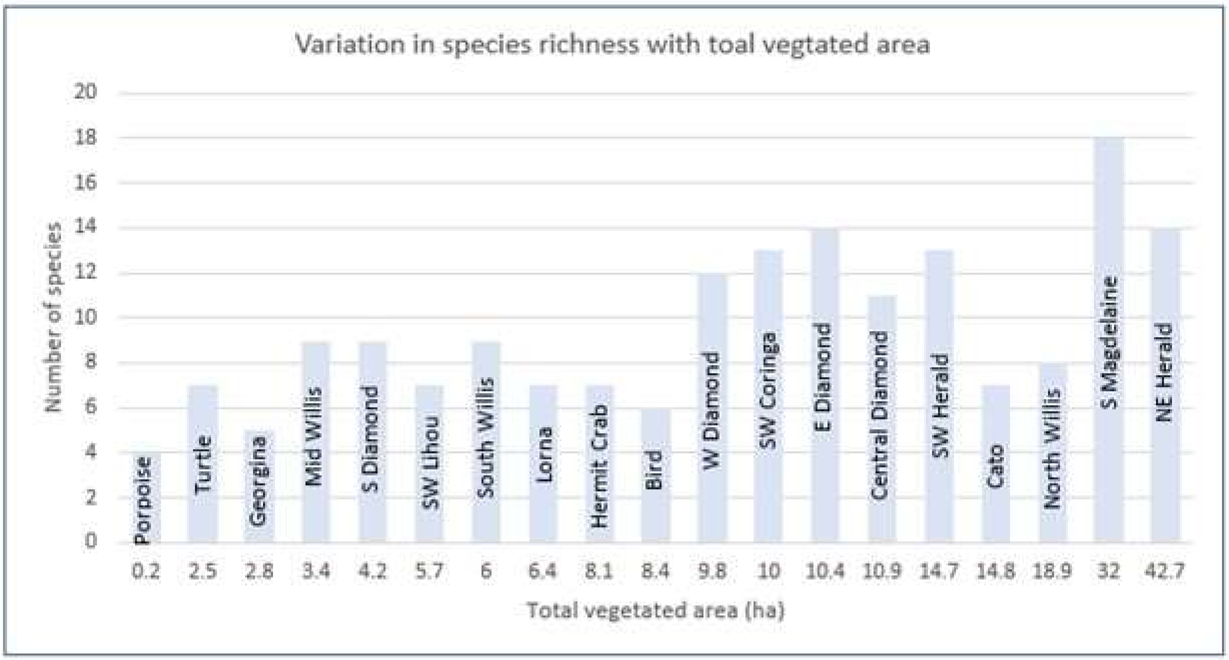

Figure 5 Variation in species richness with vegetated area of Coral Sea cays

The most abundant species across all the vegetated cays were determined based on (a) number of sites in which the species was recorded and (b) % cover in sites in which they were present. Averaged percent covers included in the dot points below refer to the average for sites in which the species was present.

Only ten species in total were recorded on the five cays surveyed in 2022. This is excluding species that were observed during the opportunistic visits to East Diamond Islet, NE Herald Cay and SW Herald Cay.

During the 2022 survey:

- The herbs, *Achyranthes aspera* (chaff flower), *Boerhavia albiflora* var. *albiflora* (tar vine), *Portulaca oleracea* (pigweed) and *Lepturus repens* (stalky grass), were present on all five cays surveyed.
- The herbs, *Stenotaphrum micranthum* (beach buffalo grass) and *Tribulus cistoides*, were present on all cays except Porpoise Cay.
- The grass, *Sporobolus virginicus* (marine couch) and the shrub *Argusia argentea* (octopus bush) were each present on two cays with *Sporobolus virginicus* present on North Cay (Willis Islets) and Mid Islet (Willis Islets) and *Argusia argentea* present on Cato Island and Mid Islet (Willis Islets).
- The shrub *Abutilon albescens* (lantern bush) was only recorded on Mid Islet (Willis Islets) and the forb, *Lepidium englerianum* (beach peppercress) was only recorded on North Cay (Willis Islets).

The following numbers of plant species were recorded and collected during the May/June 2022 surveys on cays where they have not previously been recorded:

- three species on Porpoise Cay (Wreck Reef)
- three species on Bird Islet (Wreck Reef) including one new weed species
- two species on Mid Islet (Willis Islets)
- eight species on North Cay (Willis Islets)

The 2022 surveys confirmed that all previously recorded species on each of the cays surveyed during this voyage are still present on these cays.

Species recorded on individual cays as well as frequency in sites and average covers for each species on each cay are listed in the tables in the Cay summaries Section.

Tribulus cistoides (bulls head burr) is a summer annual and although it was quite abundant in some locations, it is likely to be more abundant in the summer months.

Species recorded on all Coral Sea cays during the May/June 2022, July 2021, October 2020 (South Islet, Willis Islets), December 2019 voyages, the 2016 Bush Blitz voyage and as well as (previous) records from earlier trip reports and Herbarium records are tabulated in *Appendix 2* for comparison. The table also indicates species that are currently present on each of the cays, whether these were recorded prior to the 2016 voyage and also the last recorded date for species on each cay which were recorded prior to 2016 and are no longer present on the cay.

Weeds

Three weed species were found on Bird Islet (Wreck Reefs). No weeds were found on any of the other cays visited during the 2022 voyage.

Coconuts

Coconuts were among the most abundant of the drift fruit and seeds observed on the shorelines of all the cays. Despite the large number arriving on the shorelines, no well-established plants were observed on any of the cays visited, nor are there any records of their natural establishment elsewhere on any Coral Sea cays, indicating that they are not part of the natural Coral Sea cay flora. The reasons for this may be that they are either no longer viable on arrival or conditions on these cays do not favour their longer-term establishment, possibly due to properties of the cay soils, unsuitable climatic regime, or disturbance by cay fauna such as turtles or hermit crabs or a combination of these. Coconuts should not be planted on Willis Island or other human use cays in the region as this could result in increase in viability of coconuts reaching the shorelines of other Coral Sea cays due to reduced time in the ocean. During the 2022 voyage, only one germinated coconut seedling was seen. This was on the beach on Mid Islet (Willis Islets) in a location where it is unlikely to continue to grow.

Vegetation communities

No *Pisonia grandis* (pisonia) communities were present on any of the five cays surveyed and mapped during the 2022 voyage.

Argusia argentea (octopus bush) shrublands were present on the shoreline of Cato Island and Mid Islet (Wilis Islets). The interior vegetation of these two cays was predominantly grasslands and herblands except for an *Argusia argentea* shrubland on a low area on the northwestern end of Mid Islet (Willis Islets). No other tree or shrub communities were present on the five cays surveyed and mapped and the vegetation of the Bird Islet and Porpoise Cay on Wreck Reefs and North Cay (Willis Islets) consisted entirely of open to closed grasslands and herblands.

Drift seeds

The most common drift seeds found on the shorelines of the cays were:

- *Barringtonia asiatica* (box fruit)
- *Calophyllum inophyllum* (Alexandrian laurel)
- *Cocos nucifera* (coconut)
- *Entada phaseoloides* (matchbox bean)
- *Heritiera littoralis* (looking glass mangrove),
- *Mucuna* sp.
- *Rhizophora* sp.(mangrove)
- *Terminalia catappa* (beach almond).

The drift seeds collected during the 2021 and 2022 voyages have been sent to the Queensland Herbarium for identification. No identifications have been received at the time of submission of this report and these will be provided to PAD as soon as they are finalized.

The drift seeds have most likely originated from Pacific islands and travelled to the Coral Sea cays via the ocean currents described earlier in this section. Although most species of drift seeds collected were numerous and widely distributed on the shores of the cays visited during the 2022 voyage, with the exception of *Argusia argentea*, none are currently growing on these cays and none have been reported growing on any Coral Sea cays in previous reports, indicating that conditions on Coral Sea cays are not suitable or the seeds are non-viable by the time they reach the shorelines.

Photographs of samples of drift seeds collected on each cay during the voyage are shown in *Appendix 6* Photographs of drift seeds collected during 2922 voyage

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Bird habitat provided by vegetation

Pisonia grandis communities on Coral Sea cays provide nesting habitat for black noddy (*Anous minutus*), brown noddy (*Anous stolidous)*, great frigatebird (*Fregata minor)*, lesser frigatebird (*Fregata ariel)* and red-footed booby (*Sula sula*) as well as cover for some red-tailed tropicbirds (*Phaethon rubricauda*).

The roots of *Pisonia grandis* trees help to stabalise wedge-tailed shearwater burrows and the absence of plants on the forest floor provide easy access to the burrows. On cays with no pisonia forest, wedge tailed shearwaters nest in burrows in grasslands and herblands on the crests, plateaus and upper slopes. Black noddies also nest on the branches of the *Argusia argentea* shrubs.

The grassland and herbland communities were the preferred nesting habitat for large numbers of ground nesting seabirds, particularly sooty terns (*Onychoprion fuscatus)*, brown noddies (*Anous stolidous)* and brown boobies (*Sula leucogaster)* with the largest numbers nesting in bare or sparsely vegetated patches within these communities. The *Stenotaphrum micranthum* (beach buffalo grass)/ *Boerhavia albiflora* var. *albiflora* (tar vine) open grasslands just landward of the shoreline were also favoured nesting sites for these species.

Nesting red-footed boobies (*Sula sula*) and frigatebirds (*Fregata* spp.) were abundant on the branches of the *Argusia argentea* (octopus bush) shrubs. Lesser frigatebirds also nest on the ground in depressions in the interior herblands.

Masked boobies (*Sula dactylatra*) commonly nest in the sparse shoreline vegetation (vegetation unit 1a) and on the bare sand seaward of the vegetation.

Nesting red-tailed tropicbirds (*Phaethon rubricauda*) favoured nest sites under low bushy *Argusia argentea* shrubs and were also abundant under large flat slabs of coral rubble or coral rubble on various cays.

Nesting roseate terns (*Sterna dougalli*), black-naped terns (*Sterna sumatrana*) and New Caledonian fairy terns (*Sternula nereis exsul*) are not dependent on vegetation cover, nesting on vegetation free areas on sand spits and on unvegetated cays.

Photo 3 Adult and adolescent red-footed boobies roosting in *Argusia argentea*, Mid Islet (Willis Islets).
Joy Brushe ©

Photo 4 Sooty terns nesting in bare patches amongst grassland on North Cay (Willis Islets).
Joy Brushe ©

Photo 5 Red-tailed tropicbird nesting under the protection of an *Argusia argentea* shrub on NE Herald Cay
Joy Brushe ©

Photo 6 Lesser frigatebirds nesting in a depression in closed herbland on Bird Islet
Joy Brushe ©

Photo 7 Red-footed booby nest protected from the wind in low *Argusia argentea* shrubs on Cato Island.
Joy Brushe ©

Photo 8 Masked boobies nesting in bare patches in herbland vegetation Joy Brushe ©

Photo 9 Black noddy nesting on *Pisonia grandis* branches on NE Herald Cay
Collette Bagnato © Queensland Government

Photo 10 Wedge-tailed shearwater burrows in *Pisonia grandis* forest floor on NE Herald Cay
Collette Bagnato © Queensland Government

Ecological values of the vegetation communities

The vegetation on the cays plays a role in soil development and by accumulating, cycling and releasing nutrient to the surrounding reef. It also helps to stabilise the cays.

The grasslands and herbland communities that dominate most of the vegetated Coral Sea cays are important habitat for ground nesting seabirds. Only very small areas of these communities are present on the southern and central Great Barrier Reef cays.

In addition to the ecological value of providing habitat for seabirds, the vegetation communities of the Coral Sea cays have significant biodiversity value in their own right.

The "dry" tropical vegetation of the Coral Sea cays is an important link with Indo-Pacific region and the Melanesian Islands with the assistance of seabirds and prevailing east-to-west South Equatorial Currents (Batianoff et al*., 2*008 and 2009a).

The cay communities are unique to the coral cays, differing from those on the mainland and continental islands in substrate and prevailing climatic conditions as well as structure and floristic composition of the vegetation. The vegetation communities on the Coral Sea cays differ from those of both the Pacific/Melanesian cays and those of the Great Barrier Reef.

Similar vegetation communities in the southern Great Barrier Reef have all been allocated a Queensland Biodiversity Status of "Of Concern" because of their limited geographic extent. The Coral Sea cays are under Commonwealth management and the vegetation of these cays has therefore not been assessed using the Queensland biodiversity classification framework. Given the small size of the Coral Sea cays and the small total area of each of the vegetation communities, these communities would also qualify for an "Of Concern" Biodiversity Status based on limited geographic extent using the Queensland framework.

Soils

Results of soil analyses for all 2022 sites are tabulated in *Appendix 5.* Soil analysis of individual sites is discussed for each BioCondition monitoring site in the Cay Summaries section.

Data for comparison with other locations presented in this section are from soil samples collected and reported during the following surveys:

- Coringa Herald Cays during 2006 and 2007 (Batianoff et al., 2008 and Batianoff et al., 2010).
- Capricorn Bunker cays in the Southern Great Barrier Reef during 2007 to 2008 (Batianoff et al., 2012).
- South Islet (Willis Islets) in October 2020 (Brushe, 2021).
- Diamond Islets (Tregrosse Reef) and Lihou Reef Cay samples collected in July 2021 (Chapman et al., 2022).

These citations will not be used again in this section.

The graphed data are averages of soil samples collected at a range of depths in the A hoirizons grouped into vegetation types (*Argusia argentea* shrublands, interior grasslands, interior herblands, interior *Abutilon albescens* shrublands, *Pisonia grandis* communities) for:

2022 Coral Sea cay sites	Each site sampled on the 2022 voyage.
2020 South Willis sites	Each site sampled at South Islet (Willis Islets) in the 2020 survey.
2021 Diamond Islet sites 2021 Lihou Reef cay sites	Averages for all sites in each vegetation type on each cay sampled during the 2021 voyage.
2006/2007 Coringa Herald cay sites	Averages (all cays) of all sites in each vegetation type sampled during the Coringa Herald 2006-2008 survey.
2007/2007 Cap Bunker Cay sites	Averages (all cays) in each similar vegetation type sampled during the Capricornia Cays 2006/2007 survey (excluding Lady Elliot Island which was a highly disturbed weed dominated cay).

Note: The Coringa Herald and Capricorn Bunker data are averages of values obtained from all cays for each vegetation type and therefore do not show variation between cays.

Cay soils are derived solely from coral and other organisms growing on the reefs. The calcareous sand substate is very low in nutrient and contains no clay. These soils usually have little to no profile development beyond some accumulation of organic matter in the A-horizon. The absence of a B-horizon indicates recent development and/or a lack of weathering from the original marine deposits (Batianoff et al., 2012). Organic input from seabird guano, turtle nesting and decaying vegetation provides soil nutrient and enhances nutrient availability to plants. Rainfall and oceanic aerosols also contribute to soil development.

Batianoff et al. (2012) demonstrated that soil nutrient concentrations were higher and pH lower in the surface soils than in deeper horizons. Soil pH is lower in surface soils than at depth due to leaching of the carbonate by rainfall. Although no samples were collected deeper than 30cm during the 2022 voyage, with some exceptions, levels of organic carbon, Colwell phosphorus, potassium and sodium generally decreased with sample depth. Levels of nitrogen were also higher in the surface soil samples than deeper samples at both Bird Islet sites and the two Willis Islet sites and the Willis Islet sites showed an increase in pH with increasing depth.

Previous analyses of both Coral Sea and Capricornia Cay soils demonstrated that there is a relationship between soil properties, associated vegetation community and distance from the shoreline and increasing elevation of the cay interior. Soil generally varies from white sand +/- coral rubble fragments on and adjacent to the shoreline to light coloured /grey-brown sandy soil on the slopes and darker coloured sandy soils with increasing organic content on plateaus and higher elevation sites in cay interiors where vegetation is denser and soils have had a longer time to develop. Soil nutrient levels are lowest on beaches and shorelines and highest in the interior soils while pH is highest in the beach and shoreline soils and lowest in the higher elevation interior organic soils with long established vegetation.

The lower elevation interior herbland on North Cay (Willis Islets) and the interior *Argusia argentea* (octopus bush) community on Mid Islet (Willis Islets) had less developed, lower nutrient soils with higher pH than the higher elevation interior sites on Cato Island and Bird Islet (Wreck Reefs).

The graphs below show comparisons of the 2022 soils data with previous data collected at comparative depths from similar vegetation communities in the Coral Sea cays and the Capricorn Bunker cays. Batianoff et al. (2012) previously noted that soil nutrient levels in the Coringa Herald Coral Sea cays were considerably higher than those in samples from the Capricorn Bunker Cays in the southern Great Barrier Reef. The higher nutrient status of the Coral Sea Cays compared to the southern GBR cays is evident in the graphs.

Although no soils were sampled from *Pisonia grandis* communities in 2022, 2006/2007 (Coringa Herald cays) and 2007/2008 (Capricorn Bunker cays), soils data from *Pisonia grandis* communities have also been included for comparison with the other vegetation communities sampled.

Chemical composition of soil varies with recent climatic conditions which affect nutrient input from decaying vegetation and guano and rate of nutrient leaching from surface soils. Nutrient levels will also vary with time of the year in which the samples were collected due to both variation in climatic conditions and intensity of seasonal bird nesting. These factors must be considered when interpreting comparative data and may explain some of the variations between samples evident in the graphs below. Also while the samples collected during the 2020, 2021 and 2022 surveys provide good data for individua sites, the small number of samples collected nay not be sufficient to provide representative data in each vegetation type for accurate comparison.

pH

Soil pH on cays is typically alkaline due to the high carbonate content. Alkaline pH can make several of the trace elements, particularly iron, manganese and zinc, unavailable to plants.

Soil pH in the 2022 samples ranged from 8.15 (20-30cm depth in the interior herbland on Cato Island) to 9.65 (20-30cm depth in the interior *Argusia argentea* shrubland on Mid Islet, (Willis Islets).

The two sites on Mid Islet and North Cay (Willis Islets) had higher average and median pH values than soil samples from all other locations.

The vegetation type with the lowest pH soils were the Coringa Herald interior *Pisonia grandis* forests. Averaged Coringa Herald *Pisonia* soils have lower average pH than average pH from the Capricorn Bunker *Pisoina grandis* communities, although the soils in the largest, most well developed forests on the Capricorn Bunker cays (Masthead and North West Island) have the lowest pH (7.08 and 7.33 respectively) within the available data sets.

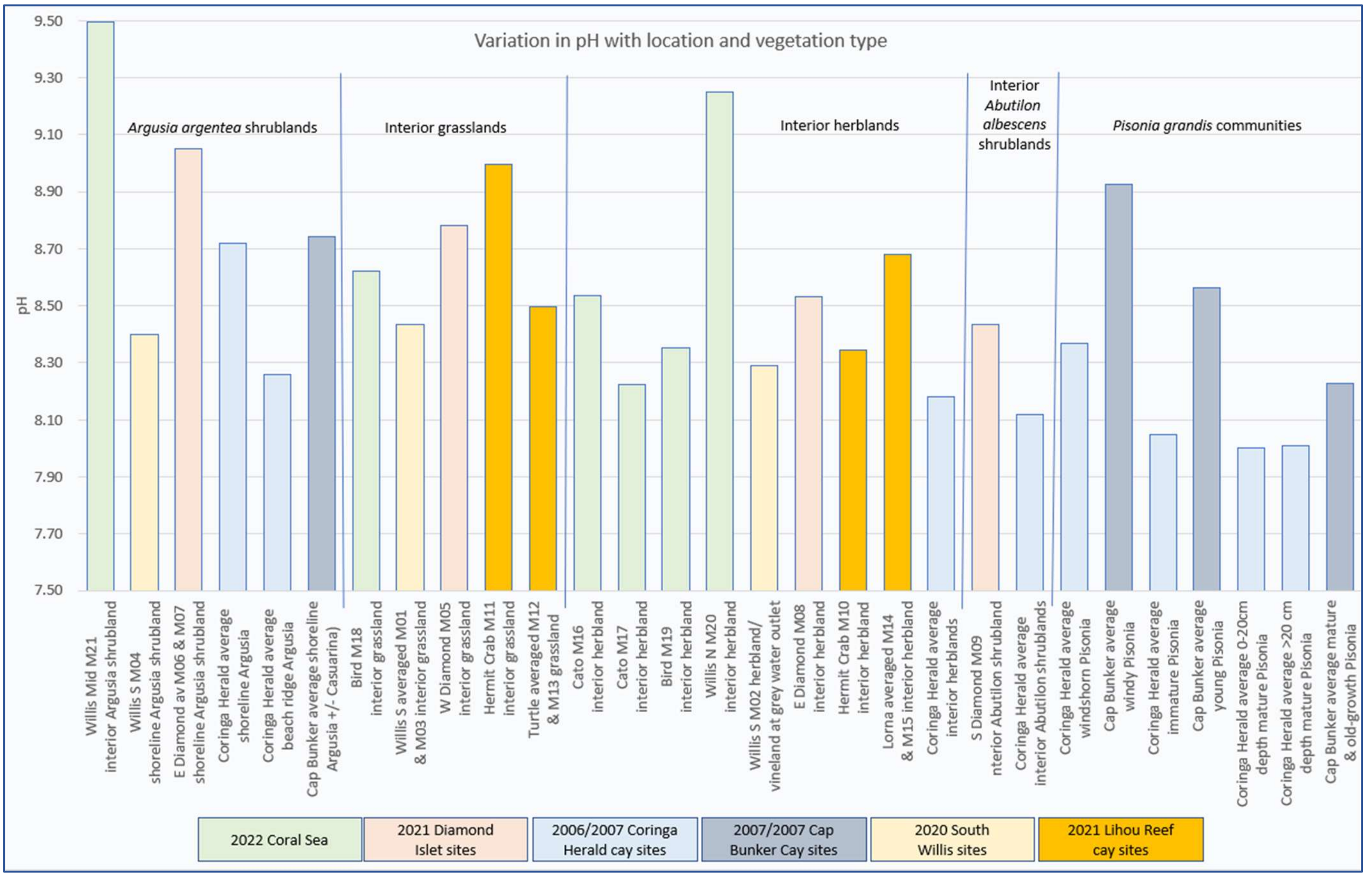

Figure 6 Variation in soil pH with location and vegetation type

Electrical conductivity (EC)

EC is an indication of the availability of nutrients in the soil. Beach sand has low EC and EC increases with increasing organic content. The *Argusia argentea* (octopus bush) and other coastline communities typically have lower EC than interior communities.

EC of the 2022 samples ranged from 0.07 dS/m at the 20-30 cm depth in the *Argusia argentea* shrubland on Mid Islet (Willis Islets) to 0.68 dS/m in the 20-30cm depth of the interior herbland on Cato Island.

Interior *Pisonia grandis* communities in the Coringa Herald cays have the highest EC values within the available datasets.

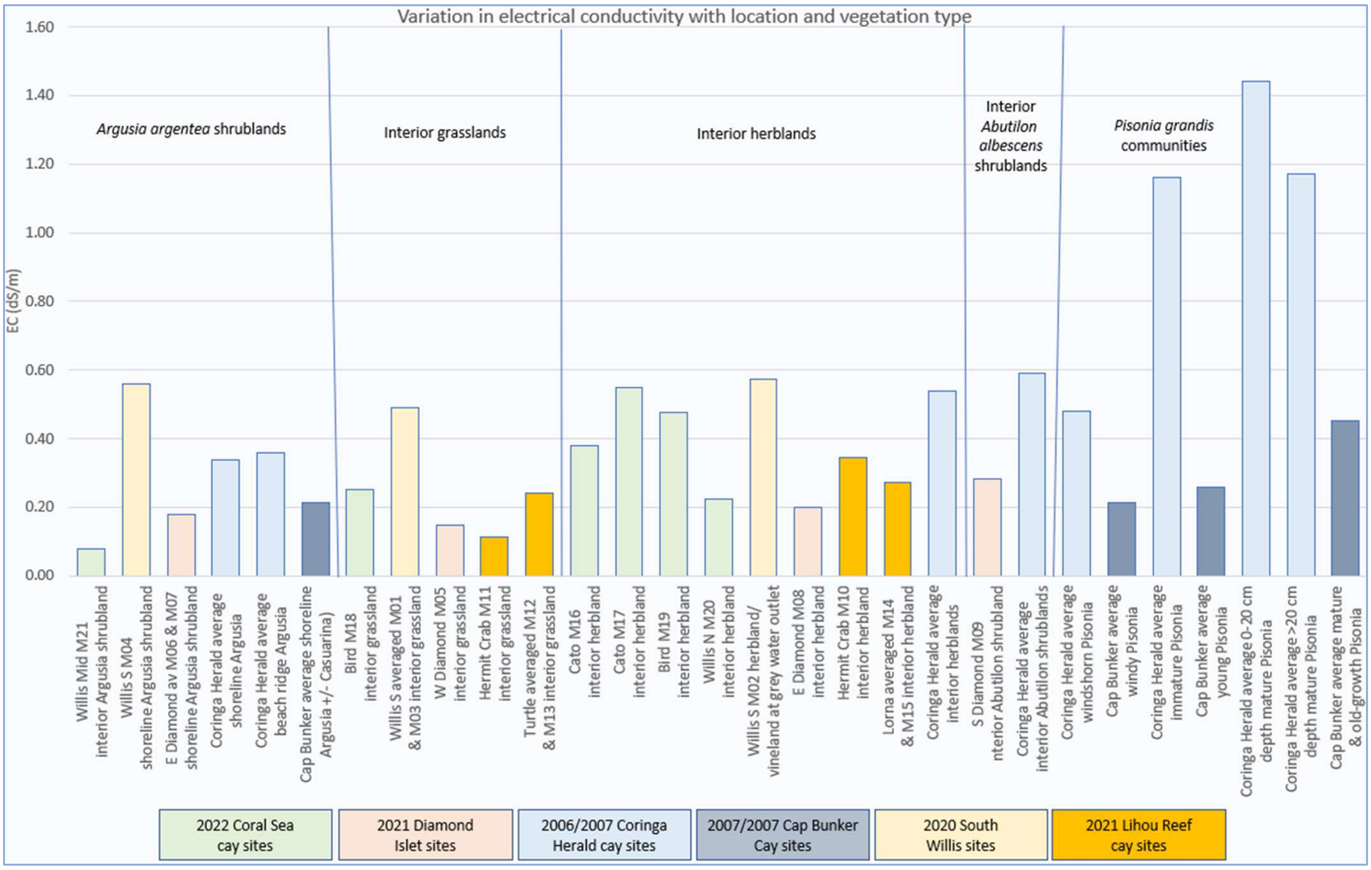

Figure 7 Variation in soil electrical conductivity with location and vegetation type

Total Nitrogen (N)

Cay soils are low in nutrient and typically have low total nitrogen levels. Levels of N are related to organic content.

Levels of N in the 2022 samples ranged from 0.05 wt % in the interior *Argusia argentea* shrubland on Mid Willis (Willis Islets) to 0.65 wt % on the surface of the closed herbland on the interior plateau on Bird Islet (Wreck Reefs).

The 2022 Willis Islets sites had lower levels of soil N than the sites on Cato Island and Bird Islet.

Levels of N in the available data sets were very variable. Within the available datasets, coastal *Argusia argentea* communities have the lowest N levels and the Coringa Herald soil samples had higher N levels than similar communities in other locations.

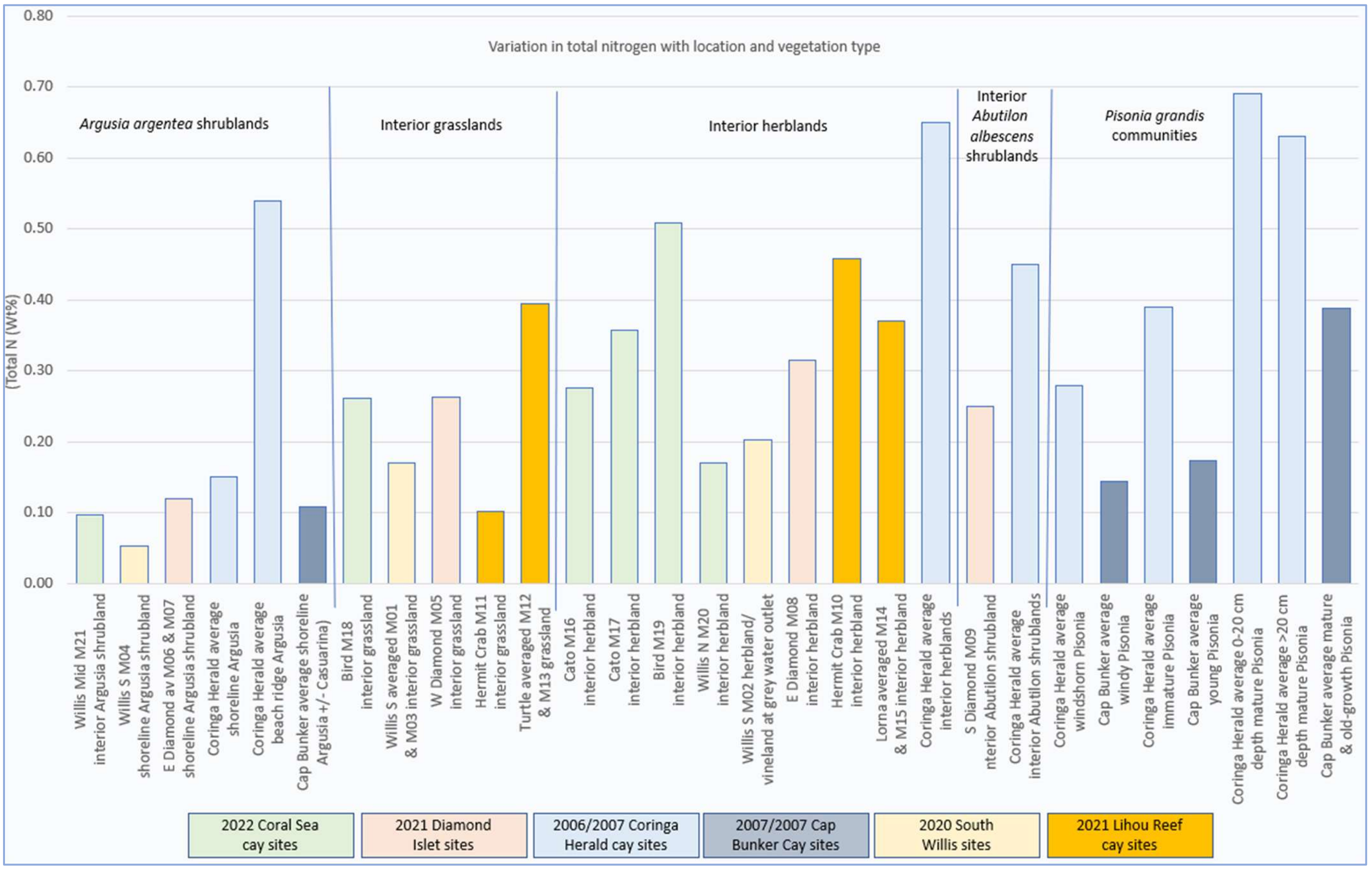

Figure 8 Variation in soil total nitrogen with location and vegetation type

Total Carbon (TC) and Organic Carbon (OC)

TC levels were high in all data sets as would be expected with the calcium carbonate mineralogy of the calcareous sand.

Levels of TC in the 2022 samples ranged from 9.59 wt % in the 20-30cm depth of the interior herbland on Cato Island to 14.05 wt % in the surface soil of the *Portulaca oleracea* herbland on the slopes of Cato Island.

Levels of OC in the 2022 samples ranged from 0.37 wt % at the 20-30 cm depth in the interior *Argusia argentea* shrubland on Mid Islet (Willis Islets) to 9.02 wt % in the surface soil of the *Portulaca oleracea* herbland on the slopes of Cato Island.

The soils in the earlier samples from both the Capricorn Bunker and the Coringa Herald cays generally have lower TC levels than the more recent Coral Sea samples.

Within the available datasets, the Diamond islets and Lihou Reef cays have the lowest OC levels although the TC levels at these cays were comparable with levels from all the recent Coral Sea samples.

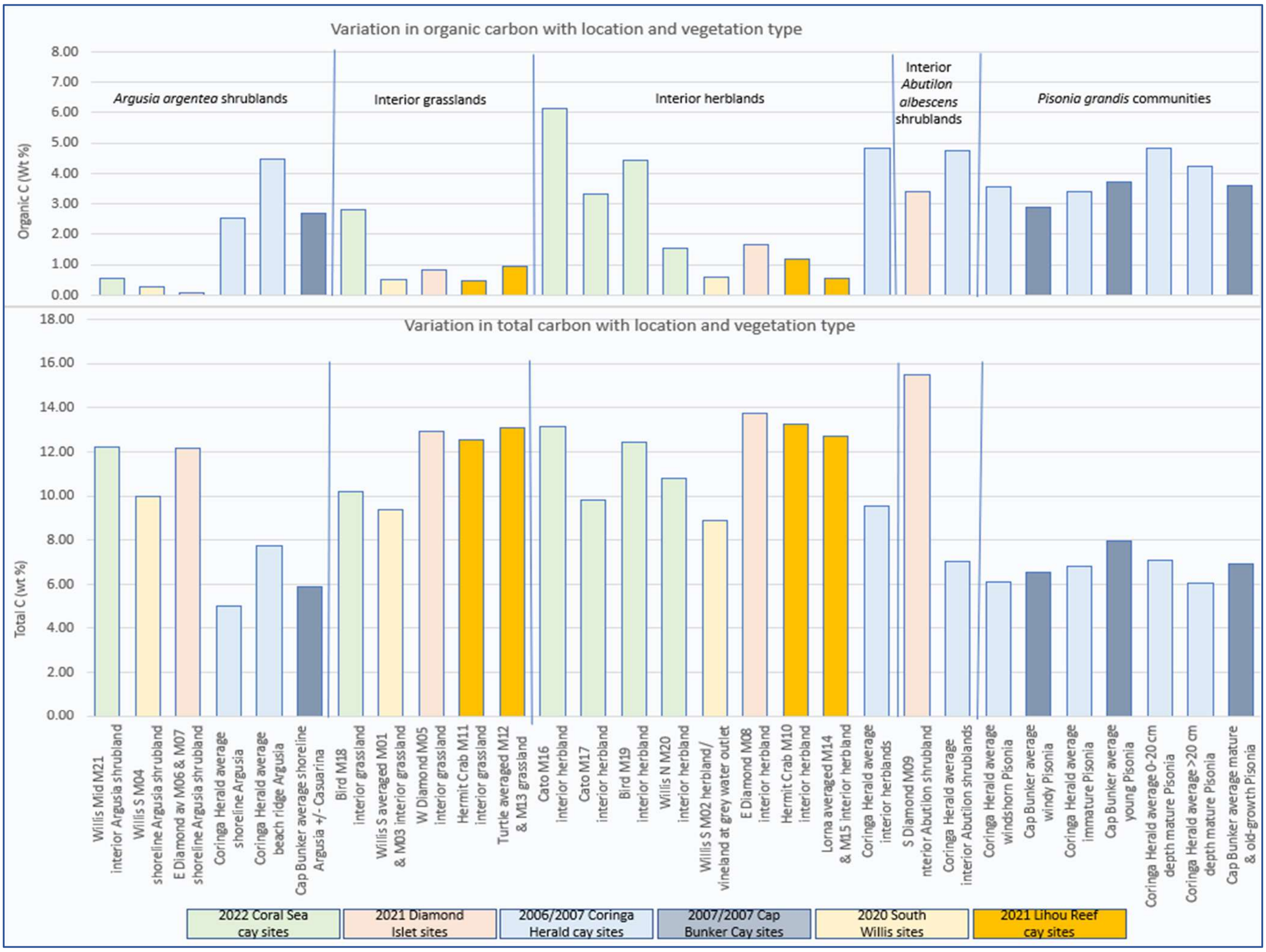

Figure 9 Variation in soil total and organic carbon with location and vegetation type

Phosphorus (P)and Colwell Phosphorus (Col P)

Levels of P were high at all sites, as would be expected with deposition of guano by large populations of nesting seabirds. Col P is a measure of the phosphorus in the soil that is available to plants.

Levels of P in the 2022 samples ranged from 2,600 mg/kg at the 20-30cm depth in the closed herbland on North Cay (Willis Islets) to 52,200 mg/kg in the 10-20cm depth in the interior herbland on Cato Island. Comparative total phosphorus levels were not available for some data sets.

Col P levels ranged from 151 mg/kg in the 20-30cm depth in the interior *Argusia argentea* shrubland on Mid Islet (Willis Islets) to 1,567 mg/kg in the 20-30cm depth in the closed herbland on the interior plateau on Bird Islet (Wreck Reefs).

In the 2022 samples, Col P levels were considerably lower in the Willis Islet sites than the Cato Island and Bird Islet sites and levels of P and Col P at the Cato Island and Bird Islet sites were higher than those from all other Coral Sea cays sampled within each vegetation type.

Soil Col P levels were considerably lower in the Capricorn Bunker cays than in the Coral Sea cays.

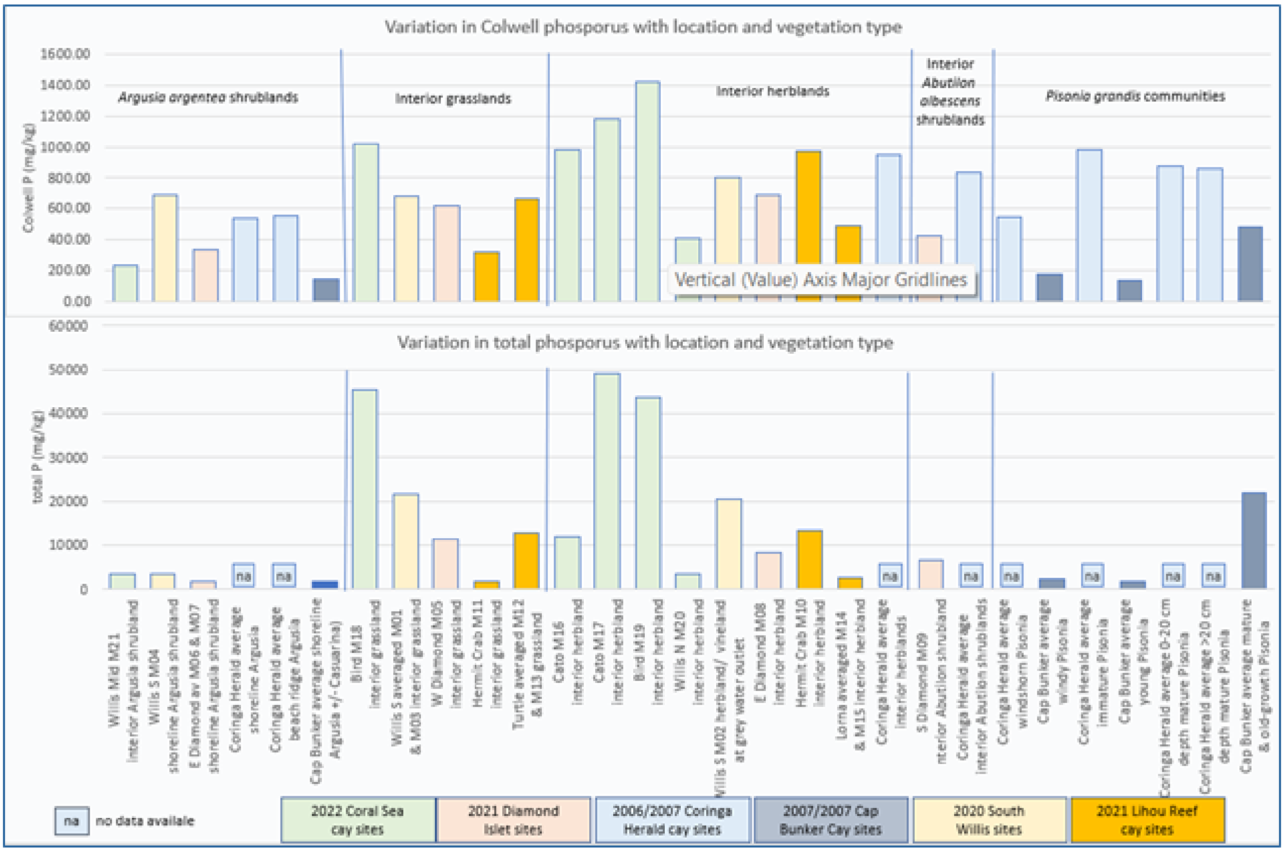

Figure 10 Variation in soil total phosphorus and Colwell phosphorus levels with location and vegetation type

Total and exchangeable calcium (Ca), potassium (K), magnesium (Mg), sodium (Na) and cation exchange capacity (CEC)

Comparative total element data was not available for all locations.

CEC

CEC is a summation of the levels of exchangeable Ca, exchangeable K, exchangeable Mg and exchangeable Na and is a measure of the total negative charges within the soil that adsorb plant nutrient cations. CEC describes the soils capacity to supply nutrient cations to the soil solution for plant uptake. According to Morrison (1990) CEC is closely related to organic content.

CEC was higher in the South Islet (Willis Islet) sites than at all other sites in similar vegetation types.

Coral Sea samples from all locations generally had higher CEC than those of the Capricorn Bunker cays in similar vegetation types.

Total calcium (Ca) and exchangeable calcium (exchangeable Ca)

Levels of Ca in cay soils are high due to the calcareous mineralogy of the cay sands.

Levels of Ca in the 2022 samples were quite similar in all samples, ranging from 35.5 wt% to 40.3 wt% with 2022 sites on both Willis Islets sites having slightly higher levels than those on Cato Island and Bird Islet (Wreck Reefs).

Exchangeable Ca levels in the 2022 samples were slightly lower in the Willis Islet sites than the Cato Island and Bird Islet (Wreck Reefs) sites and ranged from 9.36 cmol (+)/kg in the 10-20cm depth sample from the interior *Argusia argentea* shrubland on Mid Islet (Willis Islets) to 14 cmol (+)/kg from the surface soil in the closed herbland on the interior plateau on Bird Islet (Wreck Reefs).

Exchangeable Ca levels were higher in all the South Islet (Willis Islet sites) than in any other location sampled (data not available for total Ca).

Exchangeable Ca levels were lower in the Capricorn Bunker soil samples than the Coral Sea samples in similar vegetation types.

Total potassium (K) and exchangeable potassium (exchangeable K)

Levels of K in the 2022 samples were higher in the Cato Island and Bird Islet (Wreck Reefs) sites than the Willis Islet sites and ranged from 94 mg/kg in the 20-30cm depth sample from the closed herbland on a slope on North Cay (Willis Islets) to 420 mg/kg on the interior plateau on Bird Islet (Wreck Reefs).

Levels of exchangeable K in the 2022 samples were also higher in the Cato Island and Bird Islet (Wreck Reefs) sites than the Willis Islet sites and ranged from 0.01 cmol (+)/kg from the deeper samples from each site on both Mid Islet and North Cay (Willis Islets) to 0.27 cmol (+)/kg from the 10-20cm depth in the closed herbland on the interior plateau on Bird Islet (Wreck Reefs).

Exchangeable K was highest in the Coringa Herald cay samples.

Total magnesium (Mg) and exchangeable magnesium (exchangeable Mg)

Levels of Mg in the 2022 samples ranged from 0.15% in the 20-30cm depth sample from the interior herbland on Cato Island to 1.5% in the 20-30cm depth of the closed herbland on a slope on North Cay (Willis Islets).

Exchangeable Mg levels in the 2022 samples ranged from 0.76 cmol (+)/kg in the 10-20cm depth in the interior *Argusia argentea* shrubland on Mid Islet (Willis islets) to 3.16 cmol (+)/kg in the surface soil in the closed herbland on the interior plateau on Bird Islet (Wreck Reefs).

Exchangeable Mg was highest in the Coringa Herald Cay samples and higher in the Coral Sea cay samples than the Capricorn Bunker cay samples in similar vegetation types.

Total sodium (Na) and exchangeable sodium (exchangeable Na)

Levels of Na ranged from 0.29% from the 20-30 cm depth in the closed herbland on a slope on North Cay (Willis Islets) to 0.41% from the 20-30cm depth in the *Portulaca oleracea* herbland on a mid-slope on Cato Island.

Levels of exchangeable Na in the 2022 samples were slightly higher in the Cato Island and Bird Islet (Wreck Reefs) sites than in the Willis Islet sites and ranged from 0.07 cmol (+)/kg in the 20-30cm depth sample from the interior *Argusia argentea* shrubland on Mid Islet (Willis Islets) to 0.76 cmol (+)/kg in the surface soils in the interior herbland on Cato Island.

Exchangeable Na levels were higher in the South Islet (Willis Islet) sites than in sites from all other locations in similar vegetation types.

Exchangeable Na was highest in the Coringa Herald Cay samples and higher in the Coral Sea cay samples than the Capricorn Bunker cay samples in similar vegetation types.

Figure 11 Variation in soil cation exchange capacity and calcium, potassium, magnesium and sodium levels with location and vegetation type

Aluminium (Al)

Levels of Al in the 2022 samples ranged from 0.37mg/kg in the 20-30cm depth sample from the interior *Argusia argentea* shrubland on Mid Islet (Willis Islets) to 26 mg/kg in the 10-20cm depth sample from the closed herbland on the interior plateau on Bird Islet (Wreck Reefs).

Levels of Al were variable. The grey water outlet site on South Islet (Willis Islets) had very high levels of Al compared to other locations.

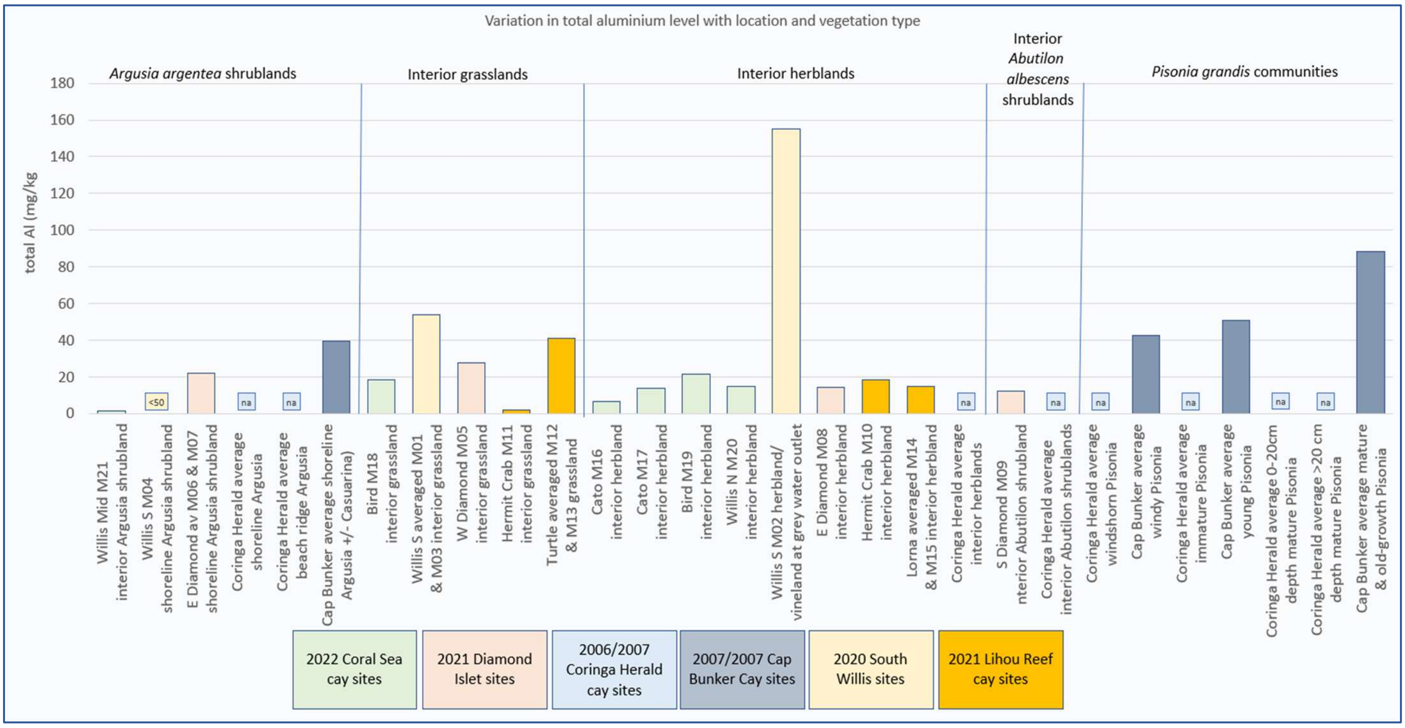

Figure 12 Variation in soil aluminium levels with location and vegetation type

Sulphur (S)

Calcium domination of the exchange complex can result in a low capacity to retain S. Some S, however, is made available continuously by solution of the coralline materials plus atmospheric S derived from sea-spray (Morrison 1990).

Levels of S in the 2022 samples ranged from 0.42 % in the 20-30cm depth sample from the interior herbland on North Cay (Willis Islets) to 0.55% in the surface soils of the interior herbland on Bird Islet (Wreck Reefs).

S level levels at all six sites sampled in 2022 were higher than any levels from soils previously obtained at all other cays. It is not known why S levels at all these sites should be so high, particularly when the sites were spread over such a large geographic area and were from differing vegetation and soil types. A possible source of the S may be acid rain produced in the sulphur dioxide plume that was reported over northern Australia and the SW Pacific Ocean following the volcanic eruption of the Hunga Tonga-Hunga Ha'apai volcano in January 2022. Refer to images on these websites:

https://airs.jpl.nasa.gov/resources/241/sulfur-dioxide-detected-after-tonga-volcano-eruption-in-2022/
https://www.esa.int/ESA_Multimedia/Images/2022/01/Sulphur_dioxide_from_Tonga_eruption_spreads_over_Australia

Elevated levels of N, however, were not apparent as would also be expected from NOx gases in the volcanic plume.

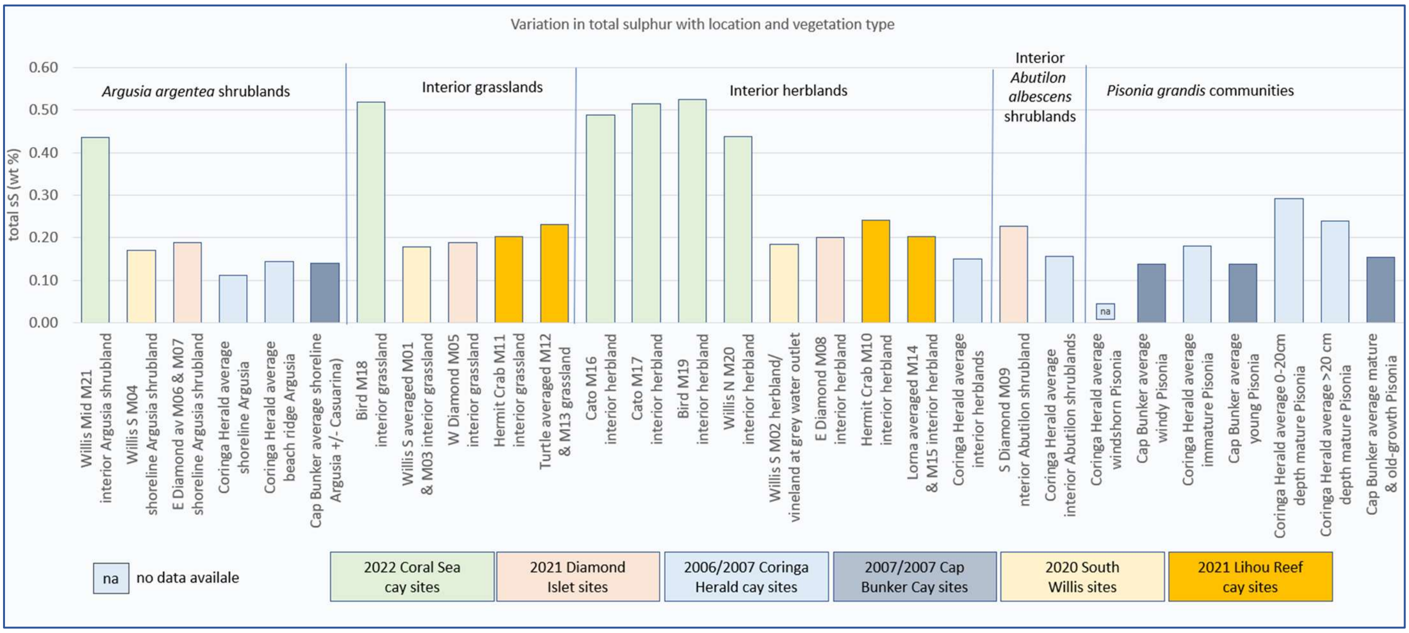

Figure 13 Variation in soil sulphur levels with location and vegetation type

Trace elements: copper (Cu), iron (Fe), manganese (Mn), zinc (Zn)

Levels of all the trace elements (particularly Fe) in the soil samples collected at the grey water outlet on South Islet (Willis Islets) were all considerably higher than those in all other datasets.

Levels of all the trace elements in the 2022 soil samples were higher in the Cato Island and Bird Islet samples than those from the Willis Islet sites.

Copper (Cu)

Levels of Cu in the 2022 samples ranged from 0.57mg/kg in the 20-30cm depth sample from the interior *Argusia argentea* shrubland on Mid Islet (Willis Islets) to 21.8 mg/kg in the surface soils of the interior grassland on Bird Islet (Wreck Reefs).

Levels In the Capricorn Bunker soil samples were generally lower than the Coral Sea soil levels.

Iron (Fe)

Levels of Fe ranged from 1.75 mg/kg in the 20-30 cm depth in the 20-30cm depth sample from the interior *Argusia argentea* shrubland on Mid Islet (Willis Islets) to 88.29 mg/kg in the surface soils of the interior grassland on Bird Islet (Wreck Reefs).

Manganese (Mn)

Levels of Mn ranged from 1.57 mg/kg in the 20-30 cm depth in the 20-30cm depth sample from the interior *Argusia argentea* shrubland on Mid Islet (Willis Islets) to 8.47 mg/kg in the surface soils of the interior herbland on Bird Islet (Wreck Reefs).

Zinc (Zn)

Levels of Zn ranged from 3.81 mg/kg in the 20-30cm depth sample from the interior herbland on North Cay (Willis Islets) to 132.5 mg/kg in the surface soils of the interior grassland on Bird Islet (Wreck Reefs).

Levels in the Capricorn Bunker cay soils were lower than those in the Coral Sea samples.

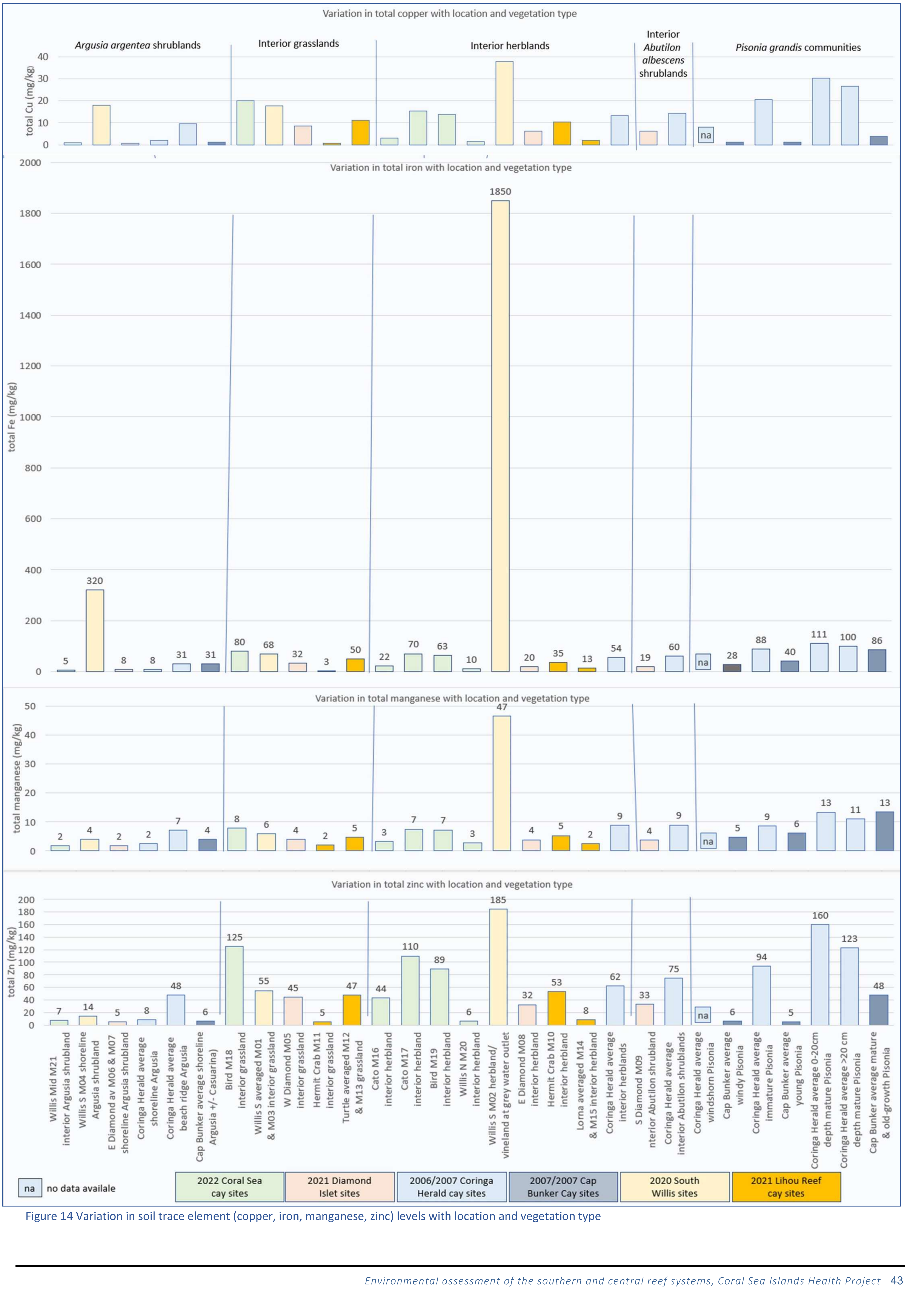

Figure 14 Variation in soil trace element (copper, iron, manganese, zinc) levels with location and vegetation type

1.2 Birds – Andrew McDougall

Aims

- Catalogue species and breeding effort
- Identify presence of threats

Methods

Voyage data focus on cays, but also includes sightings made at sea and on exposed reef flats.

At sea sightings were opportunistic. Species were recorded from observations made at the back of the boat. Latitude and longitude (datum GDA94) were recorded along with the species and their respective number (see Part 3).

Cay surveys were conducted as follows:

- Record species enroute to cay from main vessel. Often birds will flush from beaches and not be recorded again. Photographic recording is preferred when conditions allow.
- Check for nesting birds along beach at point of access. Identify exclusion areas and alert researchers of these areas. This protects small species such as black-naped terns which have cryptic, easily disturbed or destroyed nests.
- Circumnavigate the cay, noting roosting and nesting preferences. This also provides the opportunity to record roosting shorebird species.
- Collect data on breeding species, numbers and their breeding effort i.e., nests, chicks and young. Record adolescent and adult numbers.
- Survey thoroughness is determined by available survey time, species behaviour and their breeding habitat preferences (thick vegetation might not be accessible or easy to collect accurate data), and overall numbers.
- These surveys were aided by the availability of drone footage to check counts and record species in areas not covered during ground counts.
- Additional data were provided by the research team.

Field survey equipment included 12x50 binoculars, notebook, mechanical pencil, hand-held GPS (global positioning system), tally counters, a compact digital camera and a full-frame DSLR camera with the equivalent of a 600mm prime lens. Reference books were available to check known distributions of species.

Data and photographs were transferred to a laptop and backed up on portable hard drives.

Stitched drone imagery (of suitable resolution) was consulted to confirm breeding pair numbers for some species.

Results

Bird data were collected for 19 cays. Of these 19 cays, 13 were situated in the southern reef systems and six in the central reef systems.

Voyage summary data includes:

- A trip total of thirty-two species (see *Appendix* 7)
- Twenty-three seabird species, of which 13 were breeding
- Four migratory shorebird species
- Five land species including the resident Coral Sea subspecies of the buff-banded rail, *Gallirallus philippensis tounelieri*

Photography and drone imagery were reviewed to confirm seabird numbers and breeding effort.

Species and breeding effort data are included in each cay summary. A standard species table, including a standard species list, has been used throughout the report. Photographs and accompanying notes are provided where relevant.

Trip highlights included:

- The sooty tern colony at North Cay (Willis Islets) hosting over 40,000 pairs.
- Pelagic sightings of Kermadec and providence petrels, white tern, shy albatross and four species of storm-petrels.
- The record red-tailed tropicbird breeding event on the Herald Cays, with around 800 breeding pairs. This was a fortunate discovery as the Herald Cays were not part of the original trip plan. No adult birds were seen in November 2019 (McDougall 2020).

Discussion

A relevant overview is provided in the executive summary and recommendations.

Species data completeness was affected by the time available on each cay, the status of the vegetation and how many breeding species were present.

A thorough overview of brown noddy breeding effort is often not possible due to their tendency to nest in a variety of habitats and particularly when they nest within thick vegetation. Drone imagery resolution used for broad cay mapping is often not detailed enough to assist with brown noddy nest detection. Brown noddy breeding effort and age class is simplified to “present” for locations where total counts were not possible.

Acknowledgements

Thanks to everyone who made the trip successful. Special mention to the vessel operators, to Russell Gueho and Collette Bagnato for additional field observations and use of their photos to review sightings, and to Jake Sanders for capturing useful drone imagery.

1.3 Health checks – Collette Bagnato and Andrew McDougall

(Based on Chapman et al. 2022)

Introduction

Health checks are a standardised assessment tool designed for routine condition assessments of an area’s key values. This standardised approach enables the evaluation of condition trends over time.

Key values are those values that are most significant to individual protected areas, selected and defined through a Values Assessment (VA). As part of the VA the current condition and desired condition for each key value are determined by a professional panel together with the management direction, key threats, required actions and the priority of those actions.

Long term information from Health Checks will provide a good indication of the trend in condition (health), and hence alignment with the stated desired condition for the key value, and so help determine whether the current management approach is appropriate. In addition to Health Checks, where highly significant values require management intervention on a high priority protected area, detailed, targeted monitoring may be required.

In the context of a Health Check a key natural value is an ecosystem or plant community.

Health Checks use simple visual cues, require no specialist skills and have been designed to apply to all ecosystems. The criteria evaluate threatening processes and impacts (e.g., pest plants, trampling, cyclone impacts, dieback) or parameters (e.g., faunal habitat features, ground cover, recruitment of canopy species) that are good indications of condition. The Health Check assessor scores the condition of the key value (e.g. a plant community or ecosystem) at representative sites. The Health Check report uses the International Union for Conservation of Nature condition categories (Good, Good with Some Concern, Significant Concern, Critical) and definitions (Osipova *et al.* 2014) to describe the overall condition of a value across a reserve based on all the Health Check indicators relevant to the value (Melzer et al*.* 2019).

The guide for undertaking Natural Values Health Checks (Melzer 2019) is available at https://parks.des.qld.gov.au/managing/framework/monitoring/

Methods

For each Health Check, GPS locations were recorded, and photographs were taken on each of the compass points N, E, S and W. Photos were taken with an iPad Air using a Context Camera app which provides details stamped on the photo including latitude, longitude, compass bearing, date and time. Duplicate photos were taken at each Health Check site with a Nikon Coolpix P900 for higher resolution images.

Vegetated cays

The Health Checks undertaken during the May/June 2022 Coral Sea trip were baseline Health Checks for these small, remote and weather prone coral cay environments. The purpose of the Health Checks was to assess the condition of the main vegetation communities around the perimeter and interior of each cay. In addition, sites were selected with as much separation as possible and consideration given to locations on both windward and leeward sides of the cays.

Vegetation mapping is often part of planning the number and location of Health Check sites prior to fieldwork. Without available mapping for the vegetated cays, Health Check sites were chosen through a rapid assessment on site of vegetation communities present and with advice from J. Brushe. In an effort to achieve good representation of the vegetation communities present additional Health Checks were undertaken with some cays resulting in multiple Health Checks of the same community.

The vegetated cays in the central and southern reef systems support important habitats for seabirds, shorebirds and marine turtles. Both fauna and flora represent integral values of these islands. The condition of these habitat values can be inferred from the detailed vegetation assessment (condition of suitable habitat for breeding seabirds and nesting turtles) and bird species and breeding surveys undertaken by expert personnel during the trip. Marine turtle monitoring during the breeding season will further inform the value of the vegetated cays for marine turtles – breeding numbers, suitability of nesting habitat and nesting success.

Unvegetated cays

In the context of a Health Check a key natural value is an ecosystem or plant community. In the absence of a Values Assessment, the Health Check values of unvegetated cays assumes the overall values of the CSMP:

- supporting important habitats for breeding and roosting populations of seabirds, shorebirds and nesting marine turtles.

In choosing sites on the unvegetated cays the focus of the Health Checks was to identify habitat values for birds and marine turtles, habitat features and threatening processes.

The condition class for each Health Check indicator is provided in the individual cay summaries.

Results

The overall condition rating for vegetated and unvegetated cays in the central and southern reef systems was 'Good.' The exception was Bird Islet, Wreck Reefs which was rated Significant Concern/Good with some Concern. This was due to the presence of an invasive grass and two other weed species (see vegetation section in the Bird Islet summary).

The report contains summarised results and representative photos of Health Checks for each vegetated and unvegetated cay. Given the good condition of all vegetated cays it was not necessary to include all Health Check forms and photos. For the unvegetated cays relevant detail and observations are recorded in each table with representative photos to support the Health Check assessments. The unvegetated cays ranged from small intertidal sand mounds to larger cays. Unvegetated cays are known to be more mobile. The unvegetated cays surveyed were subject to varying levels of inundation. Ongoing drone imagery capture would provide insight to the movement and geomorphological processes of these dynamic systems.

Discussion

While there is overlap between Health Checks and the detailed vegetation assessment by Joy Brushe, Health Checks remain an important component of the overall monitoring undertaken during the May/June 2022 voyage. The Health Check sites will continue to allow monitoring of vegetation communities over time and can be undertaken by personnel without specialist skills, especially useful for trips when botanists are not available or where time on site is limited.

Acknowledgements

Health Check maps were prepared by Felicity Chapman.

1.4 Island Watch – Collette Bagnato and Andrew McDougall

(Based on Chapman et al., 2022)

The Island Watch tool (Armstrong, 2017) was developed by Queensland Parks and Wildlife Service as an early warning system for pest incursions and for the detection of other threats or changes to natural values to allow early management intervention.

Island Watch is a simple and rapid tool intended to be used by rangers during scheduled field management activities. Field locations can include high public use areas such as campgrounds and sites for recreational use, or significant value ecosystems where rangers undertake specific programs such as seabird surveys or weed control. All the above are a priority for high biosecurity surveillance as they represent either the most likely sites for pest incursion, or locations where new pests will cause the most serious impacts.

In addition, the Island Watch tool is used to document change or concern about other factors affecting island health such as tidal intrusion encroaching further into low lying wetlands or new sites for seabird nesting activity. Another application of the tool, particularly for seldom-visited islands, is the ability for users to retrieve information about recommended future works when preparing for subsequent visits. The tool prompts staff to be vigilant and to report on observations relevant to park management.

Methods

The Island Watch tool is available electronically on the Field Reporting Software application developed by the Great Barrier Reef Joint Field Management Program. It is also available as a questionnaire style, double-sided A4 hardcopy page to make it convenient to carry on a clipboard. The prompts to "check for change" are in text boxes that refer to observations about new or changing (spreading) weeds, pest animals, fires, seabirds, turtle tracks and nests, any monitoring or collections that took place, and where spatial data and photographs will be stored.

The form is self-explanatory, as the intent is for anyone to be able to answer the questions without special training. All information that would normally be entered into current QPWS&P data management systems must still be entered (e.g. WildNet for bird surveys), adding a note in Island Watch to refer to relevant data systems for additional detail. This procedure prevents the loss of detailed information that can be retrieved from data management systems at any time. It is not intended for the Island Watch tool to replace existing systems or databases.

The Island Watch tool was completed in paper format and is presented in *Appendix 9*.

Discussion

The Island Watch tool provided a useful snapshot of the condition of the islands, and the work undertaken during the May/June 2022 trip. It is recommended that this tool continues to be used by PAD and researchers to the island to build an ongoing database. Information can be supplemented by photographs and collections for later identification if required.

1.5 Introduced pests – Daniel Clifton and Andrew McDougall

(Based on Chapman et al., 2022)

A. Rodents

Rodents are a recognised threat to nesting birds and sea turtles. They directly threaten eggs, hatchlings and in extreme cases the adult birds themselves.

While rats (*Rattus* spp.) are widely acknowledged as the most significant rodent threat, mice (*Mus* spp.) have also been found to have major impacts (Caravaggi et al*.,* 2018; Wanless et al., 2007). Rodents are a significant biosecurity threat, readily stowing away on vessels and/or in transported equipment. In preceding centuries, it is highly likely that any landing by a vessel or shipwreck would have carried with it a very high probability of rodents getting ashore. Rodents could be introduced by private or commercial charter vessels. The highest risk lies in any activity where equipment is brought ashore. Vermin could also reach cays within discarded rubbish or items washed or jettisoned overboard by passing ships.

This monitoring component was to detect whether rodents were established on any of the vegetated cays. This information can be used to inform and prioritise future management options.

Methods

Rodent tracking tunnels baited with peanut butter, honey and/or oats were deployed for up to 1 night. Each tunnel contained a thin card tracking pad with a waterproof section in the middle. This waterproof area was liberally covered in a slow drying ink. A bolus of peanut butter was placed in the centre of this ink. The tunnels work on the principal that rodents attracted to the bait must walk through the ink and on exiting the tunnel leave their imprinted tracks on the outer sections of white card.

Tunnel deployment duration was determined by trip scheduling.

Tunnels were placed in habitat niches found on the vegetated perimeter and interior of five vegetated cays. The placement of tunnels was determined by locations supporting the most favourable shelter and foraging conditions for rodents. For example, tunnels were hidden under vegetation in a range of community types, against logs, adjacent to shearwater burrows, in rock crevices and adjacent to seabird nesting activity (available food source). Locations were fine-tuned onsite to suit the habitat conditions. Any structures or areas of disturbance were also targeted as likely locations for pest activity. All tunnels were collected at the end of the deployment and the cardboard tracking pads were examined for rodent tracks.

Results

No rodent tracks were observed in any tunnels. Hermit crab tracks and droppings were observed in most tunnels. Piles of droppings on shelter logs identified as hermit crab droppings confirmed the source of the droppings found in the tunnels.

Discussion

We conclude there were no rodents present on any of the vegetated cays surveyed. Rodent tunnels were not always set for long periods due to voyage scheduling, but we are confident the tunnels were deployed in suitable locations and the lure of the baits would have enticed any rodents present. No tracks or scats were located. A useful induction tool for anyone visiting the cays for the first time would be an information card for hermit crabs and their very rodent looking scats.

B. Ants (and other invertebrates)

The presence/absence of ant species was assessed on all vegetated islands by using baits comprised of peanut butter, oats, honey and/or tuna (cat food). Inspections were undertaken on all unvegetated cays for the presence of invertebrates.

Methods

Ant bait stations were established at each rodent tunnel. The baits were left for at least 30 minutes, after which they were checked. Abundance scores: 0; 1-50; 50-100; 100-500; and >500 were recorded for each ant species attending the bait. Voucher specimens of all species were collected and stored in vials of alcohol for identification by Queensland Museum.

Incidental hand collecting of ants and other invertebrates was also undertaken on the cays.

Results

See executive summary.

Results of ant species collected at ant bait stations and opportunistic collection of invertebrates is summarised in each cay summary.

Invertebrates were identified by Dr Chris Burwell, Dr Robert Raven and Dr Owen Seeman at the Queensland Museum.

1.6 Drone imagery – Jake Sanders and Andrew McDougall

Aim

- Obtain high resolution drone imagery of cays and their adjoining reefs, suitable for vegetation mapping, seabird monitoring and as a record to compare physical attributes of the cays over time.
- Provide georectified imagery to PAD to assist with future planning.

Methods

Field equipment

- Phantom 4 RTK drone (2x) and controller
- D-RTK 2 mobile station, includes tripod
- Aeropoint V2 (2X) for ground control points
- Notebooks, spare accessories, handheld marine VHF.

Where available, pre-departure flight parameters (as a KML file) were created using geo-spatial imagery provided by Maxar. These files were uploaded to the drone controller.

Cays with no suitable spatial imagery layers had flight parameters created on site. The drone was launched and a flight track generated on the screen. Four points were then manually plotted to create the flight boundary. This was a much more efficient way of designing a flight boundary compared to walking the low tide boundary of a cay with a handheld GPS and uploading the file that way.

Imagery capture:

- Set out the 2x Aeropoint V2 ground control points and allow at least 10 minutes for these units to obtain an accurate GPS fix. This allows time to set up other equipment.
- Set up the D-RTK 2 mobile station on a tripod, ensuring it pairs with the drone and has appropriate satellite connectivity.
- Select relevant flight plan and adjust settings and parameters as necessary.
    - Select flight height depending on allocated time on cay
    - Ratio – 3:2
    - Direction of flight path – into wind for best economy (as opposed to crosswind)
    - Image overlap 75/75
    - Margin – auto
    - White balance – auto setting generally worked well. Adjustments necessary at times.
- Execute mission, and continuously check for threats (seabirds).
- Pack up equipment in reverse order of setup.
- Images saved on a hard drive and back up hard drive for image production post voyage.
- The Drone Deploy program was used to process images and export as orthomosaic maps (as Geo TIF files).

Drone imagery results

Summarised drone imagery capture details are found in each cay summary.

Recommendations

Recommendations are outlined in the executive summary.

1.7 Marine debris – John Prichard (data provided by Tangaroa Blue Foundation)

All marine debris information is attached in *Appendix 11*.