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N62742-21-2-0002 Terrestrial Invertebrate Survey Specimen Identification and Consultation for U.S. Navy Support Facility, Diego Garcia, British Indian Ocean Territory
Request for Statements of Interest for ACQR 5859856 – **AMENDMENT 02**

## QUESTIONS AND ANSWERS

1. Who will be conducting the surveys?

   RESPONSE: Navy personnel with backgrounds in entomology and biology will be conducting the surveys. This project is for helping the Navy plan the surveys, identifying of insect and arthropod samples, and producing a report.

2. What kind of sampling and collecting methods will be used?

   RESPONSE: The Navy would like to work with the Principal Investigator on planning the surveys, but the preliminary strategy is to employ malaise traps, pitfall traps (may not be possible due to coconut crabs and other land crabs), pan traps (may need to be suspended above ground), light traps and general collecting techniques (sweep netting, beating, etc.).

3. What is the duration of the planned survey?

   RESPONSE: The survey will consist of one field visit lasting 2-3 weeks. The Navy would like to work with the Principal Investigator on the number of sampling sites, but the preliminary plan is to have 6-7 sampling sites, run traps at each site for 3 days, conduct light trapping at each site (where possible) for one night, and perform general collecting (sweep netting, beating, etc.) at each site for one day.

4. Where will collection sites be located?

   RESPONSE: The Navy would like to work with the Principal Investigator on selecting locations for sampling sties, but the current plan is to set traps and collect insects in the following areas or types of habitat: 1) Main cantonment area (area where housing quarters and associated facilities area); 2) Mixed forest west of the cantonment area; 3) Cargo/flight line area; 4) Mixed forest south of the donkey gate; 5) wetland/littoral habitat (along shore past turtle cove); 6) Mixed forest near the Minni Minni conservation area (north of plantation); 7) Native forest on East Island (if possible) or at the eastern tip of the main atoll. (See Figure 1)

   We will try to choose locations for sampling sites based on locations of transects that were used for 2017 vegetation surveys (report included).

**Figure 1 – Potential Sampling Locations**

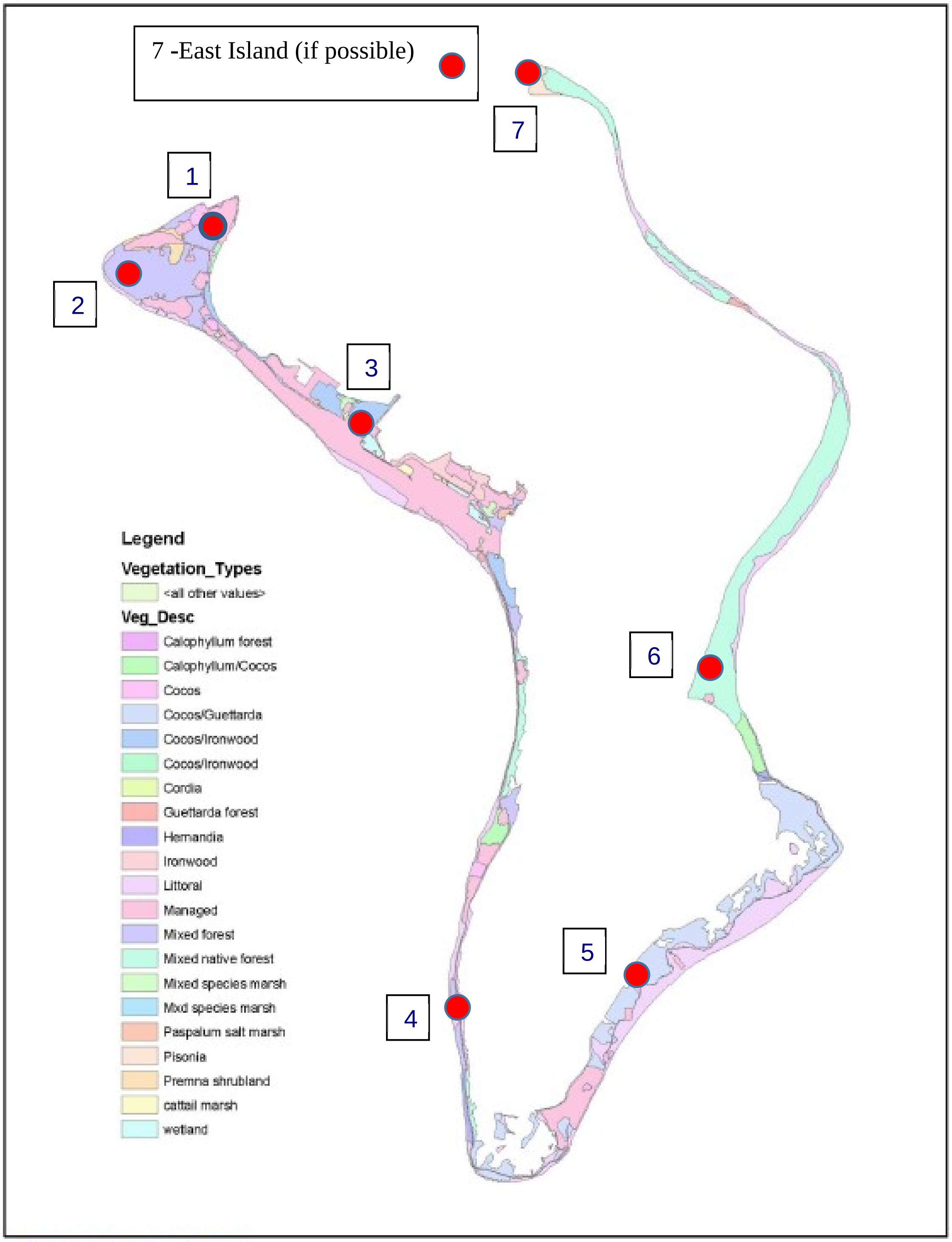


Figure 4.9 Vegetation map key

# Vegetative Survey of Diego Garcia

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# 1.0 INTRODUCTION

U.S. Naval Support Facility (USNSF) Diego Garcia is located on a tropical, footprint-shaped atoll located south of the equator in the central Indian Ocean (Fig.1). Recent Navy-funded botanical surveys of Diego Garcia were conducted in 2012 (Vogt & Guzman, 2012), 2004 (Rivers, 2004), and 1995 (Whistler, 1996). The 1995 survey looked at the taxonomy and vegetation ecology of Diego Garcia and a comprehensive plant species list was developed. The 2004 botanical survey reassessed species composition on the main atoll and its three outer islets and produced a map of the different vegetation types found on Diego Garcia. The 2012 survey meanwhile estimated tree species composition, density, basal area, and species importance throughout the atoll.

Monitoring the flora of Diego Garcia is a key component of the Integrated Natural Resources Management Plan for the facility. This vegetative survey was conducted to assess the location and total area of the broad leaf vegetative communities that occur on the main atoll and its outer islets and to document species composition within these communities. A status assessment of species considered rare or invasive was likewise completed and the establishment of repeatable survey transects within appropriate native vegetation communities so as to be able to collect quantitative data for future comparisons of vegetation changes in those areas over time was accomplished.

The vegetative survey described in this report was funded by NAVFAC Far East in support of Diego Garcia's Integrated Natural Resources Management Plan (INRMP) update.

# 2.0 STUDY AREA

Diego Garcia is a horseshoe-shaped coral atoll within the Chagos Archipelago, a large isolated complex of atolls and submerged banks (Topp & Seaward, 1999). Located seven degrees south of the equator in the central Indian Ocean, Diego Garcia is the largest landmass in the British Indian Ocean Territory (BIOT). The atoll has a perimeter of approximately 64 kilometers (37 miles) and a land area of about 2,719 hectares (6,270 acres). Its enclosed lagoon is approximately 21 kilometers (13 miles) long and up to 11 kilometers (4 miles) wide. The atoll's dry-land rim is continuous around the lagoon except for a 6 kilometer (4 mile) opening at its northernmost end in which three small barrier islands (East, Middle, and West Island) are located. The highest elevations of the atoll's rim are along its ocean side where sand dunes reach heights of 4.5 to 9 meters (15 to 30 feet) above mean sea level (NAVFAC, 2005).

Composed of a mosaic of habitats, Diego Garcia contains the only readily accessible freshwater in the Central Indian Ocean (Carr, 2011). The atoll, which at one time was host to thriving copra plantations, is now a U.S. Naval Support Facility. Developed portions of the atoll account for over 20 percent of its total land area and are comprised primarily of open habitats (NAVFAC, 2005). Low lying vegetation and grass lawns occur at communications, air operations, and cantonment facilities, with grass and scattered trees established throughout urban areas. Undeveloped lands show a gradient of forest ranging from large monotypic stands of the coconut palm (*Cocos nucifera*), to forests composed almost exclusively of mixed native trees such as Alexandrian laurel or Kamani (*Calophyllum inophyllum*), the Chinese lantern tree (*Hernandia sonora L.*), and *Neisosperma oppositifolium*.

Littoral scrub vegetation is present throughout the atoll starting at the top of the beach, above the high-tide mark, and lining almost the entire shoreline. Scaevola (*Scaevola taccada*), a dense, spreading shrub, is a dominant species as are beach heliotrope (*Tournefortia argentea*), Pisonia (*Pisonia grandis*), and the beach gardenia (*Guettarda speciosa*) (NAVFAC, 2005). Several wetland habitats, many of which contain wetland associated vegetation, are likewise found on Diego Garcia. These include ephemeral wetlands that collect rain water in low-lying areas, drainage ditches and ponds with limited emergent vegetation, as well as larger wetlands and ponds some with extensive vegetative cover. A road system provides ready access to all the habitat types that occur on the atoll with walking trails from the main road to the outer beaches or lagoon existing throughout the property.

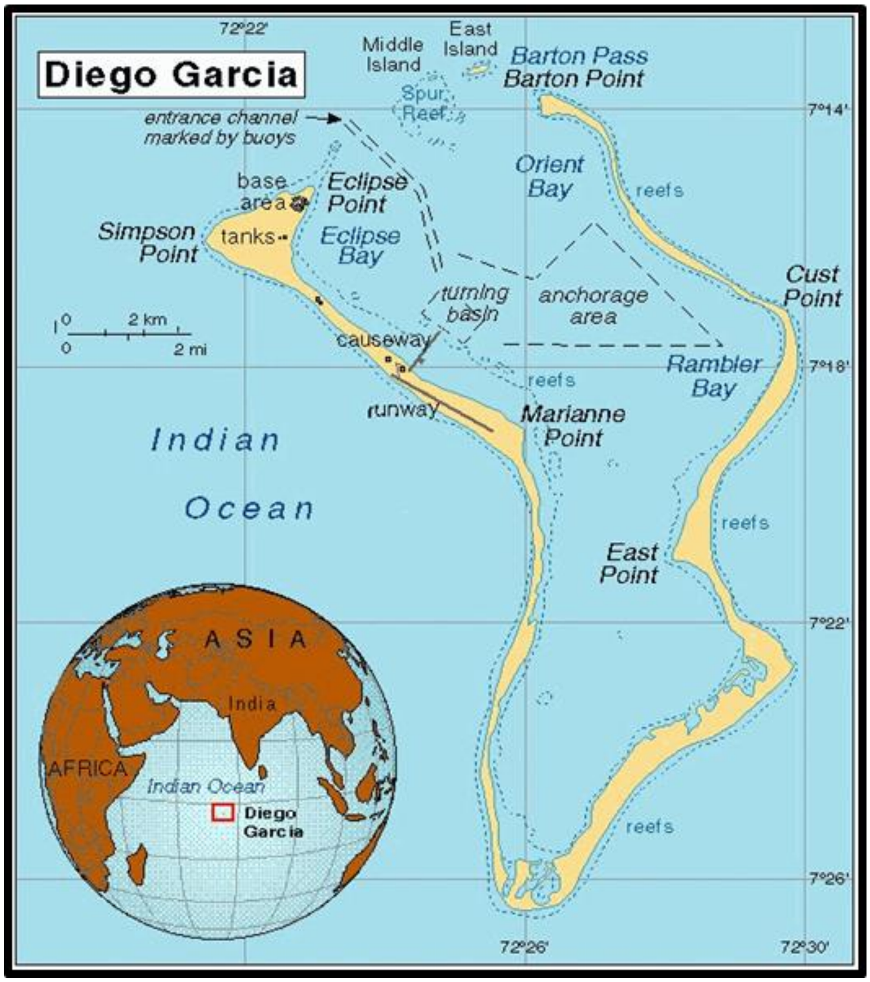


**Figure 1. Map of Diego Garcia Atoll.**

## 3.0 METHODOLOGY

Vegetation surveys were conducted at NSF Diego Garcia, by Naval Facilities Engineering Command, Pacific (NAVFAC PAC) researchers in November of 2017.

***Forest point-centered quarter surveys***

Upon arrival at the atoll, NAVFAC PAC researchers inspected forest areas and selected survey locations that would provide an adequate subset of the atoll's forested regions as well as provide spatial diversity of sample areas throughout the atoll. The result was the establishment of 109 survey stations on 13 transects (4-10 stations per transect; each station spaced approximately 50m apart). This included 2 transects on the barrier islands (one each on West and East Island). All transects and stations were surveyed once over the 8-day period, 1-8 November, 2017. Transect and survey station locations were documented using a handheld Garmin eTrex® 30 GPS unit (see Fig. 3 for a map of transect locations, and Appendix A for maps of all survey station locations and a list of their GPS coordinates).

When establishing transects, man-made structures (roads, buildings, etc.) as well as any highly altered landscapes were avoided. Random number generation was then used to establish the first survey station location for each transect within a forested area. Stations within each transect were spaced approximately 50m apart and oriented so as to bisect the forested areas (again, avoiding roads, buildings, etc.). At each survey station, the point-centered quarter method (Mueller-Dombois & Ellenberg 1974) was used to survey trees in the immediate vicinity. Specifically, the lateral distance from the station center to the nearest tree in each 90° cardinal quadrant was measured, the tree species identified, and diameter at breast height (DBH) determined. Only those trees with a DBH of 2.0cm or greater and a height of 2.5m or greater were surveyed. Compass direction was obtained using a Silva Trekker Model 420 compass, DBH was measured using a Forestry Supplier metric fabric diameter tape (Model 283D/5M) and distance was measured with a Leica DISTO D8 Laser Distance Meter. In addition, canopy cover, or overstory density, at each station center was determined using a spherical densiometer (Model-A: Forest Densiometer sold through Forestry Suppliers Inc.) according to the manufacturer's instructions (Fig. 2).

**Figure 2. Measuring Canopy Cover with a Spherical Densiometer.**

***Data Analysis***

Data from all 13 transects was analyzed separately for overall tree density (all species combined) and canopy cover. In addition, data from the 11 transects on the main atoll were combined into one group, while the two transects on the barrier islands were combined into a second group. For each of these two groups, absolute density (AD), average basal area, dominance, relative density, relative dominance, relative frequency, importance value and importance rank were calculated for each tree species recorded (Mueller-Dombois & Ellenberg 1974).

The absolute density (AD) was calculated as the total number of trees by species supported in a 100m² or 1 hectare (ha) using the formula AD = Area/D², where D = the mean distance of all distances to all trees at all stations. In order to determine the density of a specific tree species, the ratio of the number of quarters in which the species occurred to the total number of quarters was calculated. That ratio was then multiplied by the overall absolute density of trees to determine the density of each species per 100 $m^2$. Basal area (BA) was calculated with the formula BA = π(DBH2), where DBH is the diameter at breast height (1.4m) of each tree measured. Dominance of each species incorporates the average basal area of each species for all individuals surveyed multiplied by the species density in one hectare (as calculated above). Consequently, the dominance measure reflects the interaction of the biomass and density of a species, which yields the relative measure of the species ecological influence. Relative density, relative dominance and relative frequency (measures of percent distribution) were then calculated for each species in these two groups in order to derive an importance value (IV), designed to rank the overall influence of each species in a given forest area. The IV was determined by taking the sum of relative dominance, relative density and relative frequency.

## 4.0 RESULTS

### *Forest point-centered quarter surveys*

A total of 435 trees were sampled at 109 survey points on 13 transects (4 trees measured, one in each quadrant, at each survey point[1]). The 435 trees were represented by 13 different species. Table 1 summarizes the total number of trees, by species, sampled along each transect. The mean tree density estimates for all 13 transects surveyed was 6.82 trees per 100$m^2$ (±1.24 SE, range 2.6-19.6). Mean canopy cover (overstory density) for all 13 transects surveyed was 89.2% (±1.2% SE, range 80.5% – 94.6%). Canopy cover data for all transects including each individual survey point is presented in Appendix D.

**Table 1.**

Species count from transects 1-13 surveyed on NSF Diego Garcia in November 2017. Transects 1-11 occurred on the main Diego Garcia atoll. Transects 12-13 were on West and East Islands, respectively.

| | ***Transects*** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | ***Total*** |
| *Cocos nucifera (CN)* | 18 | 19 | 8 | 11 | 23 | 14 | 17 | 29 | 26 | 2 | 11 | 5 | 3 | *186* |
| *Neisosperma oppositifolia (NO)* | 9 | | | 3 | 6 | 2 | | | 1 | 24 | 23 | | | *68* |
| *Guettarda speciosa (GS)* | | | 7 | 2 | 1 | 9 | 1 | 1 | 12 | 8 | 5 | | 1 | *47* |
| *Pisonia grandis (PG)* | | | 2 | | | | | | | | | 7 | 33 | *42* |
| *Morinda citrifolia (MC)* | 4 | | 3 | 1 | 6 | 3 | 15 | 5 | 1 | 5 | 1 | | | *44* |
| *Hernandia sonora (HS)* | 4 | | | 2 | 3 | 8 | 1 | 5 | | | | | 3 | *26* |
| *Pipturus argenteus (PA)* | | 1 | | 1 | 1 | | | | | | | | | *3* |
| *Terminalia catappa (TC)* | 4 | | | | | | | | | | | | | *4* |
| *Calophyllum inophyllum (CI)* | | | | | | 1 | 2 | | | | | | | *3* |
| *Casuarina equisitifolia (CE)* | | | | | | | 3 | | | | | | | *3* |
| *Tournefortia argentea (TA)* | | | | | | | | | | | | 3 | | *3* |
| *Premna serratifolia (PS)* | | | | | | 3 | | | | 1 | | | | *4* |
| *Ficus sp. (FS)* | | | | | | | 1 | | | | | | | *1* |
| *unknown* | 1 | | | | | | | | | | | | | *1* |

[1] *Transect 12, station 1, quadrant 4 did not have a tree of suitable diameter to measure so no measurement taken and no tree sampled in this quadrant leading to a total of 435 trees sampled instead of the expected 436.*

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *40* | *20* | *20* | *20* | *40* | *40* | *40* | *40* | *40* | *40* | *40* | *15* | *40* | ***435*** |

For the rest of the point-centered quarter analyses, the transects were divided into two groups. One for all transects on the main Diego Garcia atoll (Transects 1-11), and one for the transects on the barrier islands (Transects 12 and 13 on West and East Island, respectively). For both groups, mean density (average number of trees in $100m^2$ or 1 hectare (ha)), average basal area, overall dominance, relative density, relative dominance, relative frequency, importance value and importance value rank was calculated for each tree species (Tables 2-3). Finally, for both transect groups, the frequency of tree species surveyed is presented in Figures 4-6.

**Table 2.**

Tree characteristics from combined transects 1-11 (n=380 trees) surveyed on NSF Diego Garcia in November 2017.

| *Species* | *Density/ $100m^2$* | *Mean Basal Area ($m^2$)* | *Dominance ($cm^2/100m^2$)* | *Relative Density %* | *Relative Dominance %* | *Relative Frequency %* | *Importance Value* | *Rank* |
|---|---|---|---|---|---|---|---|---|
| *Cocos nucifera* | 2.75 | 674.11 | 1855.97 | 46.84 | 35.49 | 38.10 | 120.43 | 1 |
| *Guettarda speciosa* | 0.71 | 1214.99 | 864.48 | 12.11 | 16.53 | 15.34 | 43.98 | 2 |
| *Hernandia sonora* | 0.36 | 4536.29 | 1613.81 | 6.05 | 30.86 | 5.82 | 42.74 | 3 |
| *Neisosperma oppositifolia* | 1.05 | 485.34 | 510.48 | 17.89 | 9.76 | 14.81 | 42.47 | 4 |
| *Morinda citrifolia* | 0.68 | 94.97 | 64.64 | 11.58 | 1.24 | 17.46 | 30.28 | 5 |
| *Terminalia catappa* | 0.06 | 2316.87 | 143.35 | 1.05 | 2.74 | 1.06 | 4.85 | 6 |
| *Pipturus argenteus* | 0.09 | 91.25 | 8.47 | 1.58 | 0.16 | 2.65 | 4.39 | 7 |
| *Calophyllum inophyllum* | 0.05 | 2006.19 | 93.09 | 0.79 | 1.78 | 1.59 | 4.16 | 8 |
| *Casuarina equisitifolia* | 0.04 | 1325.55 | 61.51 | 0.79 | 1.18 | 1.06 | 3.02 | 9 |
| *Pisonia grandis* | 0.03 | 313.64 | 9.70 | 0.53 | 0.19 | 0.53 | 1.24 | 10 |
| *unknown* | 0.01 | 162.58 | 2.51 | 0.26 | 0.05 | 0.53 | 0.84 | 11 |
| *Ficus sp.* | 0.01 | 58.08 | 0.90 | 0.26 | 0.02 | 0.53 | 0.81 | 12 |
| *Premna serratifolia* | 0.01 | 9.62 | 0.15 | 0.26 | 0.00 | 0.53 | 0.80 | 13 |

**Table 3.**

Tree characteristics from West and East Islands combined; transects 12 and 13 (n=55 trees) surveyed on NSF Diego Garcia in November 2017.

| *Species* | *Density/ $100m^2$* | *Mean Basal Area ($m^2$)* | *Dominance ($cm^2/100m^2$)* | *Relative Density %* | *Relative Dominance %* | *Relative Frequency %* | *Importance Value* | *Rank* |
|---|---|---|---|---|---|---|---|---|
| *Pisonia grandis* | 4.34 | 1831.91 | 7945.36 | 72.73 | 82.41 | 56.52 | 211.66 | 1 |
| *Cocos nucifera* | 0.87 | 575.25 | 499.00 | 14.55 | 5.18 | 21.74 | 41.46 | 2 |
| *Hernandia sonora* | 0.33 | 3237.17 | 1053.02 | 5.45 | 10.92 | 8.70 | 25.07 | 3 |
| *Tournefortia argentea* | 0.33 | 255.24 | 83.03 | 5.45 | 0.86 | 8.70 | 15.01 | 4 |
| *Guettarda speciosa* | 0.11 | 564.11 | 61.17 | 1.82 | 0.63 | 4.35 | 6.80 | 5 |

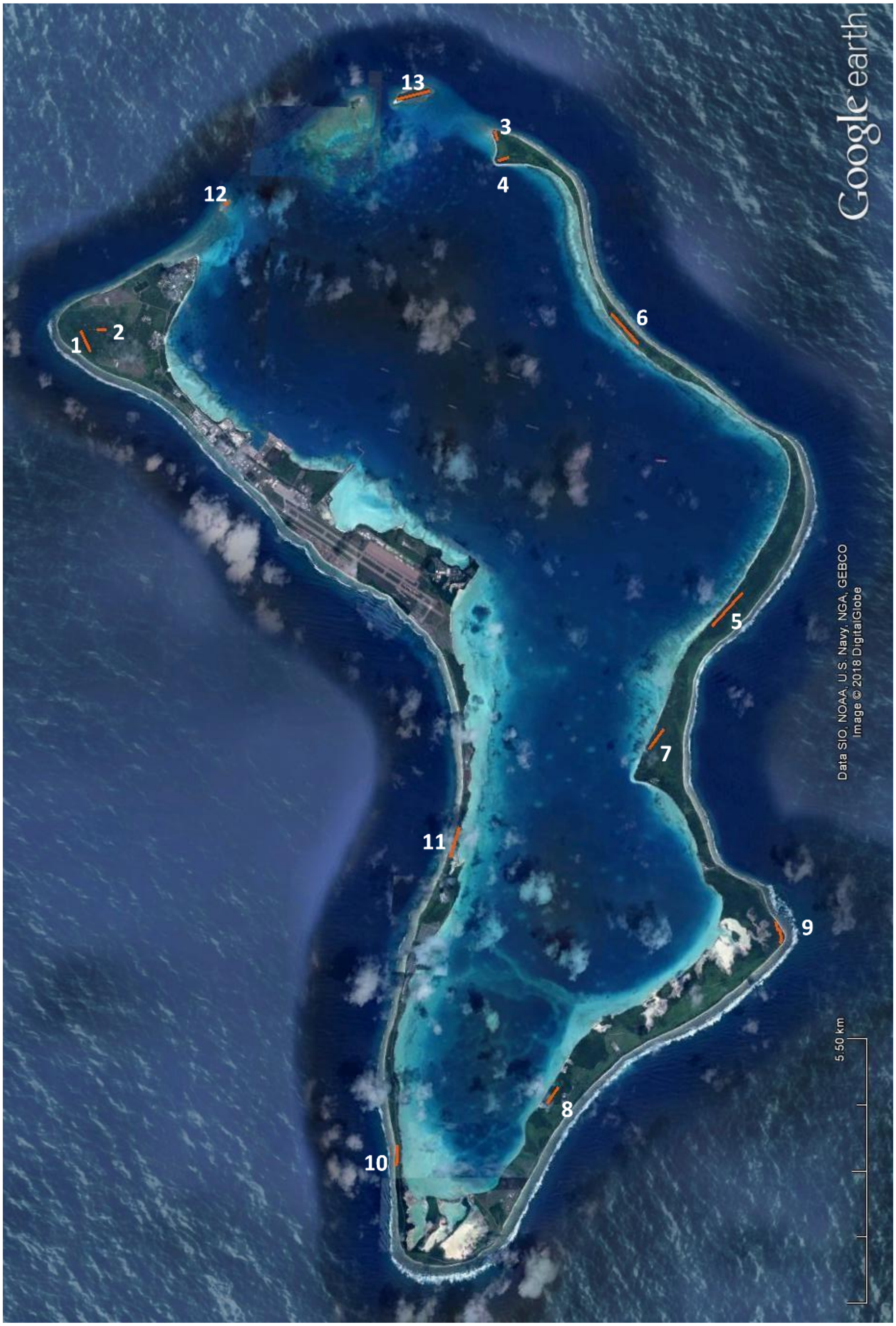


**Figure 3. Transects 1-13 Surveyed on NSF Diego Garcia in November 2017.**

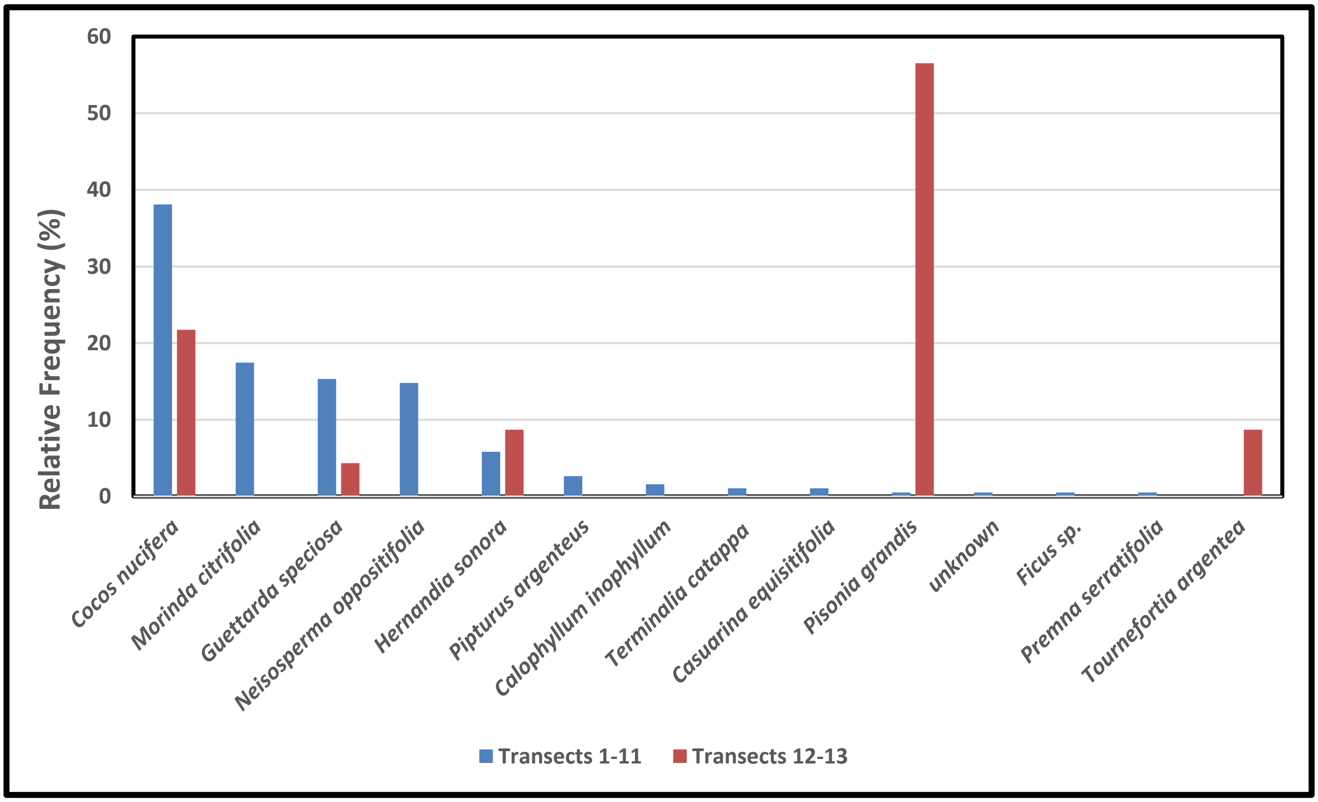


**Figure 4. Relative Frequency of Tree Species Detected at Transects 1-13 Surveyed on NSF Diego Garcia, November 2017. Transects 12-13 on West and East Island Respectively.**

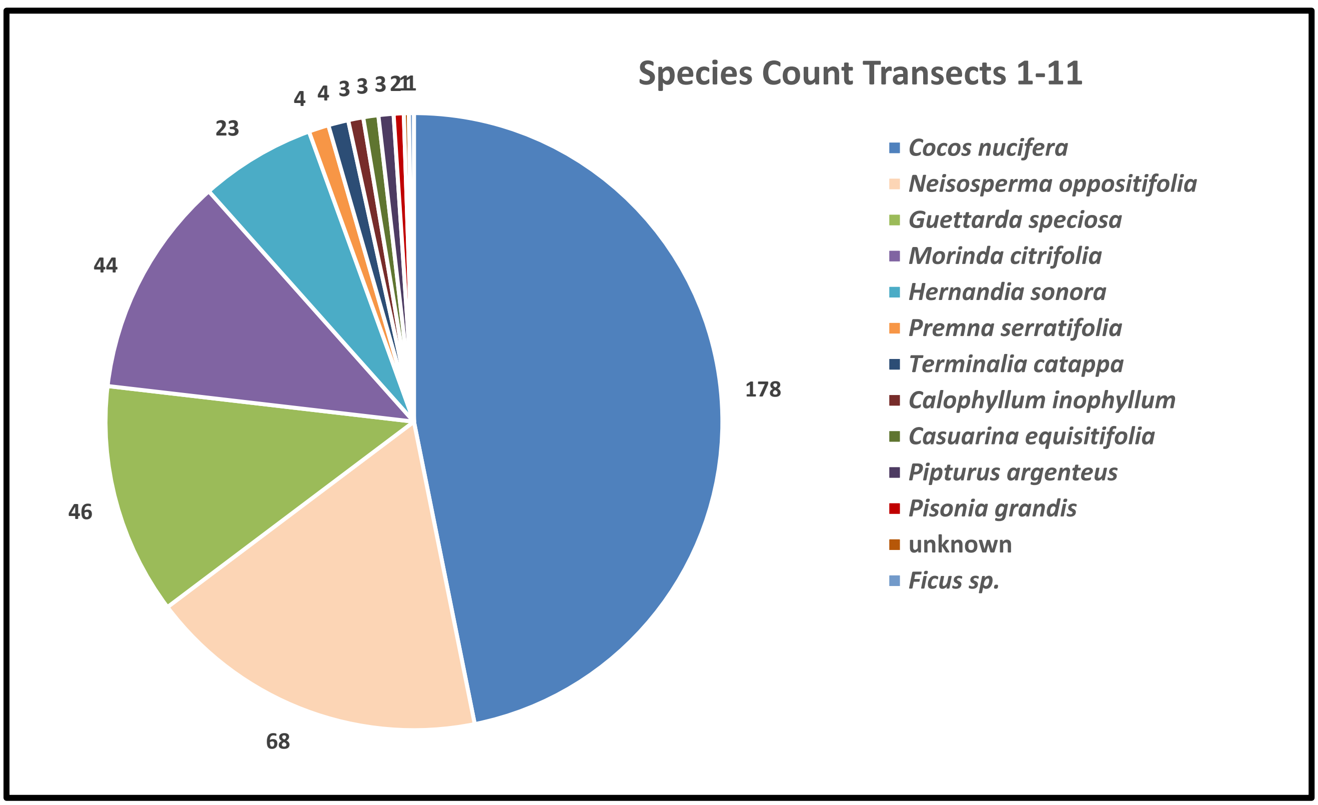


**Figure 5. Tree Species Composition within Transects 1-11 (n=380 trees) Surveyed on NSF Diego Garcia, November 2017.**

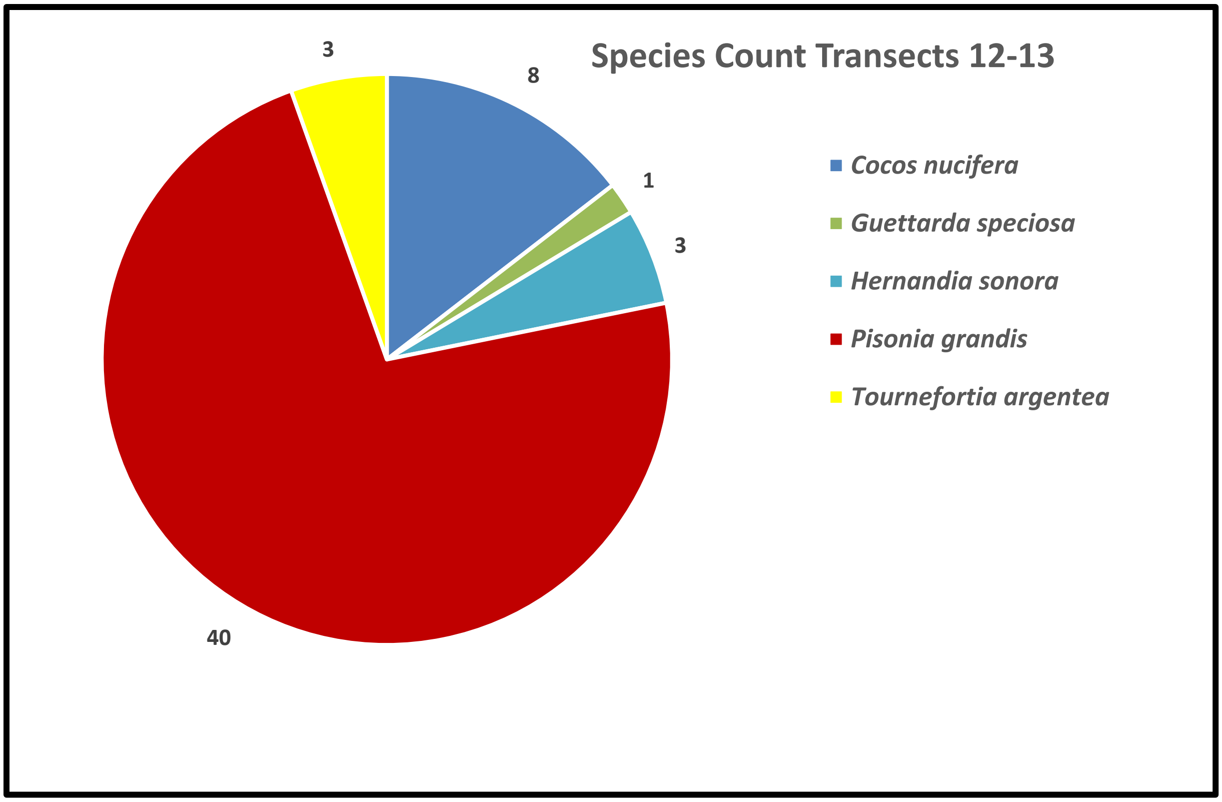


**Figure 6. Tree Species Composition on West and East Islands-Transects 12-13 (n=55 trees) Surveyed on NSF Diego Garcia, November 2017.**

## 5.0 DISCUSSION

***Forest point-centered quarter surveys***

All transects surveyed on the main Diego Garcia atoll (transects 1-11) were generally similar in that they were dominated by the Coconut palm (*Cocos nucifera*), and were comparable in their overall tree densities. Several native trees were common in the forests on the main atoll, the 2nd – 5th most important according to relative density, dominance and frequency were *Guettarda speciose*, *Hernandia Sonora*, *Neisosperma oppositifolia*, and *Morinda citrifolia*. The one exception to the Cocos-dominant transects on the main atoll was transect 10, along the southeastern portion of the atoll. In this transect, the overwhelmingly dominant species was *Neisosperma oppositifolia*, accounting for 24 of the 40 trees surveyed. The overall tree density in transect 10 was also much higher than any of the other transects with 19.58 trees per 100m², compared to an overall average of 6.82 trees per 100m² on all transects combined.

Vogt and Guzman (2012) conducted a similar assessment of trees density and diversity on the main Diego Garcia atoll. Some areas surveyed by them were similar in location to the current surveys, though some were not. Largely, results of that effort were similar to what is presented here. Overall diversity was the same (13 total species detected) though the species were slightly different. In 2012, Vogt and Guzman recorded 4 species not detected in 2017, however were found in very low numbers and in areas that were not surveyed in 2017. The four specie include *Barringtonia asiatica*, *Intsia bijuga*, *Cordia subcordata*, and *Scaevola taccada*. Note that *Intsia bijuga* (seen north of the Minni Minni area in 2012) is a native tree that is exceedingly rare on Diego Garcia. We did not detect this species in 2017, though we did not survey the precise location where they were detected in 2012. Overall tree density was similar in 2012 compared to 2017. Vogt and Guzman (2012) calculated an average density of 5.9 trees per 100m² (converted from trees per hectare as reported) compared to 6.8 trees per 100m² calculated in 2017. The 5 most dominant species on the main Diego Garcia atoll, measured by Importance Value, were the same in 2012 as what we recorded in 2017. Overall, the results suggest that the various forest communities on the main Diego Garcia atoll have not changed dramatically in the past 5 years. Vogt and Guzman (2012) did not survey the barrier islands, and thus were unable to make comparisons of tree communities on the islands versus the main atoll, nor were they able to document *Pisonia grandis* densities or the status of *Pisonia* seedlings on the barrier islands.

Transects 12 and 13 on the barrier islands (West and East Islands) had a very similar overall tree density to the transects on the main atoll (6.07 trees per 100m² compared with 5.88 trees per 100m²), however, the species frequencies were completely different. The most dominant species on these two islands was *Pisonia grandis*, accounting for 40 of the 55 trees surveyed. A likely reason *Pisonia grandis* is dominant on the barrier islands is the absence of introduced rats. Without rats, *Pisonia grandis* seeds and seedlings have been allowed to develop into trees, whereas on the main atoll these seeds and seedlings face intense predation pressure from rats. One additional potential explanation for the difference in forest structure between the barrier islands and the main atoll is the lack of fresh ground water on the barrier islands. The *Pisonia* tree is noted as being the hardiest of indigenous trees on atolls, being found where lack of fresh ground water hinders the establishment of coconut trees (Urish, 1974).

## 6.0 ANECDOTAL OBSERVATIONS

Over the course of our stay on the atoll, numerous anecdotal observations were made of the atoll's vegetation and of the terrestrial fauna's interactions with it. The following are a synopsis of notable observations with suggested management recommendations where applicable:

**Figure 7. Black Rat in Tree, Diego Garcia.**

### BLACK RATS (*Rattus rattus*)

Though largely unintentional, rats have been introduced by humans to over 80% of the world's major island groups (Shiels & Drake, 2011) and as a result of being omnivorous and having large incisor teeth, are thought to be the cause of the greatest number of plant and animal extinctions on islands (Towns et al., 2006). Black rats (*Rattus rattus*), in particular, are important seed predators known to consume a wide variety of both native and non-native fruits and seeds (Harper & Nunbury, 2015; Shiels & Drake, 2011; Meyer & Butaud, 2009; Clark, 1981).

Rats have been noted to forage for fruits and seeds both on the forest floor and in the vegetative parts of plants including the limbs of trees (Fig 7). There is a tendency for rats to favor husked over unhusked seeds (Meyer & Butaud, 2009) and larger seeds over smaller seeds (Shiels & Drake, 2011). Rats most often destroy seeds by their habit of gnawing them to pieces, however they sometimes unintentionally disperse fruits and/or their seeds by transporting them to husking stations, by eating the pericarp (outer wall of the fruit that covers the seed) and discarding the larger seed, or by eating small seeded fruits and ingesting and later dispersing the small seeds in a process known as endozoochory (Sheils & Drake, 2011; Meyer & Butaud, 2009).

For native island flora, the negative effect of rats, especially on seedling recruitment and plant regeneration, has been well studied. Rat impacts on at least 56 taxa (28 families) have been documented in the Indo-Pacific Islands alone, with some families noted to be more vulnerable to seed depredation than others (Meyer & Butaud, 2009). In the Galapagos archipelago recent studies on the foraging habits of introduced black rats determined that they are primarily herbivorous with plant material comprising 98% of their diet. Similarly, in the Pacific islands, the majority of the black rat diet (75-80%) was found to consist of fruits and seeds (Riofrio-Lazo & Páez-Rosas, 2015).

On Diego Garcia black rats are thought to have arrived with European explorers and/or settlers sometime between the early 1500s to the late 1700s; their presence was noted on the atoll by Moresby in 1878 (Stoddart, 1971b). Bourne (1886) states that "… [rats] swarm on the main island and do great destruction among the cocoa-nuts, but curiously enough, they have not yet found their way to the islets in the mouth of the lagoon." Today, black rats are found on over 90% of the Chagos landmass with confirmed presence on 26 of the archipelago's islands (Carr, 2015). Remarkably, more than 130 years after Bourne's observations were made black rats have yet to be detected on the atoll's small uninhabited barrier islands (West, Middle, and East). Nevertheless, they have invaded all terrestrial habitats on Diego Garcia's main atoll maintaining some of the highest population densities ever recorded for the species (187 rates/hectare) (Vogt et al., 2014).

**Figure 8. Husking Stations Showing Large Numbers of *Neisosperma oppositifolium* Seeds; Red Arrows Point to *Rattus rattus* Burrow Entrance Holes.**

During our vegetative survey extensive seed depredation by black rats was observed in many of the forested areas of the main atoll. A noticeable lack of seedlings despite plentiful fruit production on trees was documented, indicating potential recruitment depression. Numerous husking stations, sheltered sites where rats move their food and process it, were observed with considerable quantities of empty

*Neisosperma oppositifolium* seed husks, providing evidence of recurrent seed depredation of this native tree species (Fig. 8).

Helmsley (1886) in his *Report on the Vegetation of Diego Garcia* noted that the Gayac [*Intsia bijuga*] tree "did not increase in consequence of the rats eating the seeds as soon as they fall." Although our observations of black rats on Diego Garcia were limited, it is reasonable to assume that seed depredation by *Rattus rattus*, either singly or in concert with seed depredation by other species on the atoll, is negatively influencing the composition of the atoll's vegetative community with recruitment depression of native broadleaf species likely.

**Figure 9. *Rattus rattus* Seen Foraging During Daylight Hours.**

An additional noteworthy observation was that of a considerable numbers of black rats seen during our daytime surveys (Fig. 9). Rats are generally thought to be nocturnal, however, on Diego Garcia's main atoll both current and historic observations confirm that they are nocturnal and diurnal (Vogt et al., 2014 & Stoddart, 1971). Diurnal or daytime foraging by black rats may be due to the atoll's relatively closed forest structure, the general absence of mammalian predators (there are a small number of feral cats that remain on the atoll), and the species' extremely high population density. On Palmyra Atoll in the Pacific, Buck and Great St. James Islands in the Caribbean, and Picard Island and Aldabra Atoll in the Seychelles similar diurnal activity has been noted and is deemed to likely be a result of high population densities culminating in intense competition for food (Harper & Bunbury, 2015).

**MANAGEMENT RECOMMENDATIONS**

**Figure 10. Rat-gnawed *Guettarda speciosa* Fruit.**

It is strongly recommended that the impacts of *Rattus rattus* on native plants (in addition to native birds, native insects and other native invertebrates) on Diego Garcia be considered in further conservation planning actions. The fact that rats can inadvertently disperse the seeds of invasive species and are known to depredate and damage the seeds of a variety of the atoll's native fruiting trees including the Tropical Almond (*Terminalia catappa*), the Rose Tree or Fish Poison Tree (*Barringtonia asiatica*) (Meyer & Butaud, 2009) *Guettarda speciosa* (Fig. 10) and *Neisosperma oppositifolium* (personal observation), all of which serve as important components of Diego Garcia's forested ecosystems, makes instituting a rat control and/or eradication program within the atoll's conservation areas an important component of any proposed terrestrial natural resources restoration project.

Instituting control and/or eradication efforts for black rats is strongly recommended as is exploring ways to manage native plant species that face seed predation pressure during the fruiting season. Past studies looking at the effects of rats on tropical species, have shown that without human intervention large-seeded tropical trees may be vulnerable to local extinction (Galetti et al. 2006; Terborgh et al. 2008 in Van Etten, 2009). Our observations of both large and small-seeded tropical trees suffering from what appears to be recruitment depression due to the presence of black rats on the atoll further support the need to prioritize control of *Rattus rattus*.

In addition to carrying out rat control and/or eradication, investigation of alternatives to the more labor intensive and thus more expensive practice of transplanting nursery grown seedlings in reforestation efforts, such as direct seeding, is encouraged. Carrying out rat control in areas where invasive plant species have become established may also be beneficial, particularly during seeding periods, in reducing the potential for rat assisted seed dispersal of unwanted plants thus helping contain their spread (Shiels, 2011; Harper & Bunbury, 2015).

### *PIPTURUS ARGENTEUS*

*Pipturus argenteus* is a small seeded, animal dispersed understory tree or shrub ranging in height from 5-10 meters found on Diego Garcia. Considered to be a pioneer species *Pipturus argenteus* is often one of the first plants to colonize previously disturbed areas. The species has demonstrated prolonged seed dormancy (Enright, 1985) and dominance within soil seed banks, and in several studies has been shown to dominate seed rain (Saulei & Swaine, 1988; Whittaker et al., 1995). *Pipturus argenteus* has a wide distribution being found from the Seychelles in the Indian Ocean to the some of the more remote Pacific Islands where it is largely considered native (Fosberg, 1949; Clubbe, 2010). The fruit of this species is small (4-6mm in diameter) white, and edible with many small seeds throughout (Fig 11).

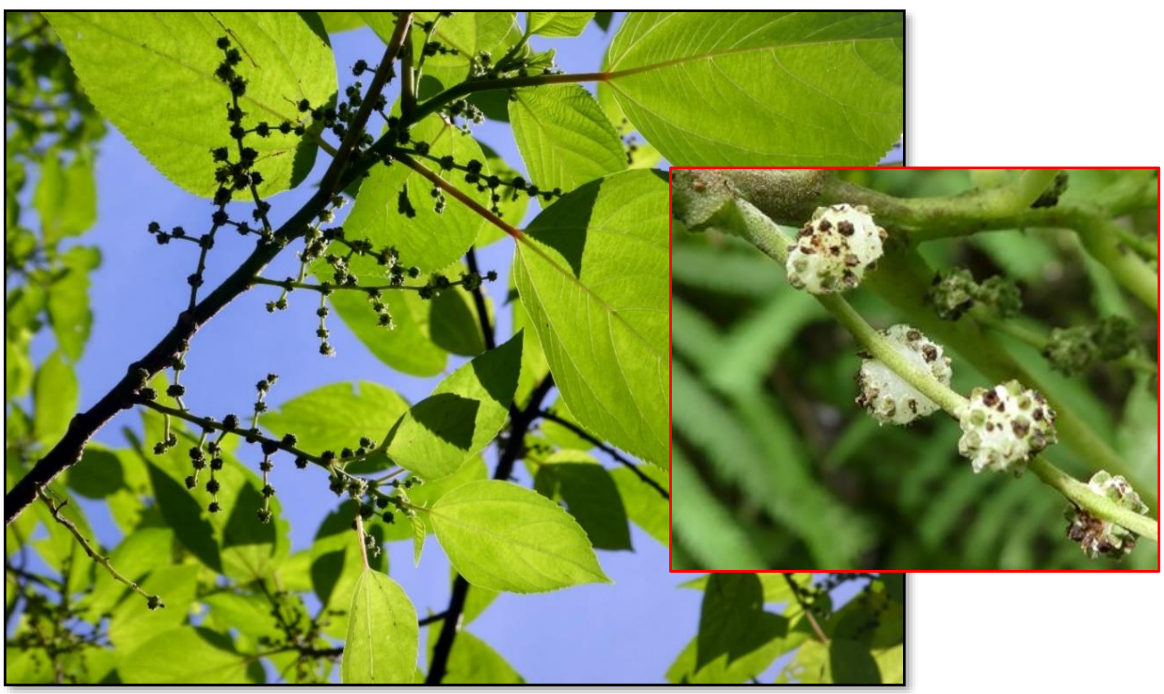

**Figure 11. *Pipturus argenteus*; Close-Up of Fruit with Numerous Small Seeds (insert).**

The status of *Pipturus argenteus* on Diego Garcia is currently unresolved. Listed as common and widespread, mainly in former plantation areas, by Topp (1988), Whistler (1996) noted its status as possibly alien and weedy while Brock (2004) classified it as native. Given the species' wide distribution in the Chagos Archipelago, it's currently known from over 25 islands (Hamilton & Topp, 2009), and its largely native status throughout the region (Clubbe, 2010) *Pipturus argenteus* is most likely indigenous to Diego Garcia and may play an important role in the atoll's forest succession. However, the species, as a pioneer plant, does possess traits similar to those of an invasive.

*Pipturus argenteus* has similar traits to an invasive species in that it is hardy and fast growing, possesses large numbers of fruits and seeds, and is a primary colonizer of disturbed areas. Carr (2011) remarked on the invasive nature of *Pipturus argenteus* on Diego Garcia's main atoll noting its proliferation in cleared areas along roads and tracks and in areas where the sun penetrated through the forest canopy. Similarly, during our survey, we observed *Pipturus argenteus* to be the dominant plant in recently disturbed areas of the atoll where it otherwise appeared to be absent or found in very low numbers.

**Figure 12. *Pipturus argenteus* on Recently Disturbed Roadside; Close-Up of Monotypic Stand (insert).**

The presence of large stands of *Pipturus argenteus* in previously disturbed areas of Diego Garcia (Fig. 12) may be partly explained by work done in other regions where the species is present. In Gogol Valley, Papua New Guinea, for example, seed rain was noted to be dominated by *Pipturus argenteus* with the species comprising 61% of all seeds germinated from trapped material (Saulei & Swaine, 1988). *Pipturus argenteus* seed rain was likewise observed to be substantially higher in recently cleared areas despite the absence of mature trees in the adjacent closed forest and *Pipturus argenteus* was also the most common pioneer tree in the study area. Saulei & Swaine (1988) hypothesized that the habits of Papua New Guinea's frugivorous birds led to significant number of seeds arriving in the closed forest from more distant sources; frugivorous birds being more prone to use the closed forest for concealment and roosting.

Tropical forests are generally recognized as having large stores of dormant seeds in their soils with densities ranging from tens of seeds per square meter to thousands (Saulei & Swaine, 1988). Tropical forest soil seed banks, which are largely composed of pioneer species, are the primary means through which tropical forests regenerate post clearing (Swaine & Hall, 1983 as cited in Saulei & Swaine, 1988). In a study looking at surface and buried seed banks in tropical forests in Indonesia, Whittaker et al. (1995) found that tree species with larger seeds lacked representation in soil seedbanks while the most numerous species were those that had particularly small seeds like those of *Pipturus argenteus* which was one of the six most abundant plants and the dominant species found in topsoil samples.

On Diego Garcia one could expect that the black rat, much like the frugivorous birds of Papua New Guinea, is widely distributing the seeds of *Pipturus argenteus.* Given the species' arboreal behavior, herbivorous diet and dominant presence within the closed forest, the black rat, in consuming the small seeded fruits of *Pipturus argenteus* and dispersing the seeds via its feces, may be contributing to the establishment of large soil seedbanks of *Pipturus argenteus* in the atoll's closed forest in areas away from where parent trees are present. Post clearing of these areas, the seeds of *Pipturus argenteus* are provided the needed conditions for germination leading to the establishment of large monotypic stands of this pioneer species.

On Diego Garcia important canopy specie have limited seed viability and are exposure to heavy seed predation both in the forest canopy and on the forest floor. These factors likely contribute to the noted absence of visible seedlings/saplings within certain portions of our survey area that were otherwise dominated by native forest canopy species. This is not a novel concept as the absence of important canopy species in soil seed banks in Indonesia was likewise noted by Whittaker and Turner (1994 in Whittaker et al., 1995) to be due to limited seed viability (less than 6 weeks for some species) and heavy predation on the forest floor.

**MANAGEMENT RECOMMENDATIONS**

It is highly probable that *Pipturus argenteus* is a native, indigenous primary colonizer and as such its dominant presence in recently disturbed areas of the atoll is to be expected. The species may play an important role in the atoll's forest succession and as such, further study of the role of *Pipturus argenteus* in the atoll's forested ecosystems is needed prior to instituting efforts to "control" this species spread.

**TERRESTRIAL HERMIT CRABS (*Coenobita* spp.)**

Terrestrial hermit crabs are native to Diego Garcia and are commonly observed on the atoll; large numbers of *Coenobita* spp. were noted on East Island during the vegetative survey particularly within the island's coastal areas (Fig. 13). Although few studies have looked at the feeding habits of terrestrial hermit crabs on atolls/islets, current literature points to the significance of their diet on the colonization, persistence, and species composition of terrestrial vegetative communities (Louda & Zedler, 1985).

**Figure 13. Large Numbers of *Coenobita* spp. on East Island Shoreline.**

*Coenobita* spp. are known to actively forage upon the seeds, flowers, and seedlings of a variety of terrestrial plant species many of which are found on Diego Garcia and its barrier islands. Such species include the seedlings of *Morinda citrifolia* and *Barringtonia asiatica*, the seeds of *Terminalia catappa*, *Guettarda speciosa*, *Scaevola taccada*, and *Calophyllum inophyllum*, as well as the bark of *Cordia subcordata*. Given the absence of rats and *Coenobita* spp. high densities and omnivorous diet, they most likely are the primary seed predator on Diego Garcia's barrier islands.

**MANAGEMENT RECOMMENDATIONS**

With atoll plants heavily depending on their fruits/seeds for recolonization and persistence, the role of *Coenobita* spp. as the primary seed predator on Diego Garcia's barrier islands may be significant and warrants further study.

**FERAL DONKEY (Equus africanus asinus)**

The donkey (*Equus africanus asinus*) was introduced to the Chagos Archipelago in 1835 with Moresby (1837) and Bourne (1886) noting its presence in the islands. Introduced to work the coconut presses and to carry large loads during the coconut plantation days, the end of the plantations in the early 1970s saw the remaining donkeys set free (Sheppard, 2016). These liberated donkeys lead to the current feral population which now inhabits the south western and eastern arms of the main atoll. A tall chain link donkey gate, installed on the south western arm, prevents donkey ingress into the airfield operations area and the north western arm of the atoll.

**Figure 14. Feral Donkey (*Equus africanus asinus*) in Diego Garcia Forest.**

Feral donkeys are known to be versatile foragers consuming a wide variety of grasses, herbs, and foliage. In areas where food sources are scarce, overgrazing by feral donkeys can lead to alteration of the vegetative habitat. Feral donkeys on Diego Garcia, much like introduced feral ungulates elsewhere, have the ability to disperse invasive plants and degrade native species habitat. Carr (2011) noted that feral donkeys on the atoll heavily browsed the native *Pisonia grandis* and exhibited a main feeding preference for saplings of the species. While *Pisonia grandis* was noted during our survey to be the dominant tree species on the barrier islands it is considered rare on the main atoll.

During our survey we repeatedly observed feral donkeys and signs of donkey presence (dung) within forested areas of the atoll (Fig.14). Pregnant females accompanied by males as well as lone males were seen and appeared to be in good health. Active foraging by numerous individuals on introduced grasses was noted in the antenna area.

## MANAGEMENT RECOMMENDATIONS

Donkeys, as both grazers and browsers, are known to consume a wide variety of plants and are foragers of native species on Diego Garcia. Carr (2011) documented their feeding preference for *Pisonia grandis*, a once abundant native species that is now rare on Diego Garcia's main atoll. Donkeys are an introduced, invasive alien species with the ability to negatively impact native plant species and their habitats. For this reason, management of feral donkeys on Diego Garcia is highly recommended.

Control methods for feral donkeys are varied and may include capture and euthanasia, control by shooting and fertility control (Sharp & Saunders, 2012). However, given that impact reduction is what's required on the atoll, use of donkey fertility control would be ineffective; the long lifespan of donkeys and their continued ability to browse and forage on native species and spread invasive species make this control method unsuitable for this location. Use of the "Judas" technique, where selected donkeys are fitted with radio transmitter collars so as to then identify companion donkeys, alongside capture and euthanasia or control by shooting is suggested. This technique has proven successful in the complete eradication of feral donkeys in some parts of Australia (Sharp & Saunders, 2012). It is highly recommended that regardless of which method is used that a well thought-out management plan first be drafted.

## WETLANDS

Wetlands on Diego Garcia provide much needed habitat for a wide variety of native birds, native insects and plants. Both seasonal and permanent, Diego Garcia's wetlands are found in a variety of landscapes including depressions (shallow pools and marshes), coastal mudflats, and fringes along running or standing water (such as drainages or tidal waters). In addition to providing habitat for native species

**Figure 15. Large Wetland Overgrown with Monotypic Vegetation, Diego Garcia.**

wetlands on Diego Garcia also provide highly valued ecosystem services helping to recharge groundwater aquifers, storing, filtering and absorbing excess sediments and storm water pollutants, and reducing flood impacts to roads, parking lots, and homes during storms and periods of heavy rain.

During our vegetative survey we observed a wide variety of wetlands many of which were completely overgrown with highly invasive hydrophilic non-native wetland vegetation (Fig. 15). Need for management including enhancement and restoration was evident. The introduction of large numbers of non-native exotic plant species to Diego Garcia within the past 200+ years has led to negative impacts on the atoll's wetlands. Exotic species such as the southern cattail (*Typha domingensis*), *Commelina diffusa* and *Ipomea aquatic*a are aggressive invaders able to out-compete native species often forming large monotypic stands that eliminate open water habitat (Whistler, 1996). Reestablishment of the hydrology, vegetation and structural characteristics of many of the atoll's wetlands is needed so as to recover the wide range of functions that previously existed and provide quality habitat for native species.

## MANAGEMENT RECOMMENDATIONS

It is highly recommended that wetlands on Diego Garcia be managed for both resident and migratory waterbird species. Management techniques used should vary depending on the wetland, target species, and the available resources on the atoll. While removal of large monotypic stands of non-native vegetation is recommended, active restoration post removal will most likely be necessary given that the seed bank will contain aggressive-invasive plants. Weeding of invasives and planting of native species post clearing may be necessary. Furthermore, prior to removal of large stands of non-native vegetation thought must be given to those waterbird species that utilize the area for loafing, feeding, and nesting; management activities should be timed to avoid negative impacts.

Development of an atoll-wide management plan for wetlands as recommended in the 2014 INRMP is strongly suggested. A multi-year approach prioritizing different wetlands based on the needed levels of management and the availability of staff and funding is advised.

**Figure 16. Golf Course Pond, 2017 Post-Vegetation Clearing (top) with Single Moorhen Nest Observed (inset); Pond in 2016 with Vegetation (bottom) Total of 12 Moorhens Observed.**

## 7.0 RECOMMENDED FOREST MONITORING AND MANAGEMENT ACTIONS

***Management Goal***

Diego Garcia's native broadleaf forest is the foundation for the atoll's surrounding terrestrial biological community, providing habitat for a variety of native bird species, native invertebrates, and native plants. The recommended management goal is to increase the area and quality of the native broadleaf forest throughout the atoll. All management actions and objectives should support this goal.

Management Activity 1: Control and eliminate non-native mammals
Strategy 1: Control and/or eradicate non-native rats & donkeys from natural resource areas.
Strategy 2: Create boundary barriers that exclude immigration of non-native mammals into natural resource areas.

Management Activity 2: Identify, control and prevent the establishment of non-native invasive plants
Strategy 1: Identify invasive plant species present in natural areas.
Strategy 2: Prioritize species and begin eradication/control of those species deemed most harmful to the environment.
Strategy 3: Conduct education/outreach campaign regarding invasive plants and rules/regulations pertaining to their import and release.
Strategy 4: Ensure that biosecurity measures pertaining to invasive plants are in place and actively followed.

Management Activity 3: Restore or enhance areas of native broadleaf forest
Strategy 1: Direct seed and/or out-plant native broadleaf forest species in recently disturbed sites and those areas suitable for restoration.
Strategy 2: Use shade cloth or other means to prevent the establishment of invasive species in those areas recently cleared for restoration.
Strategy 3: Utilize native broad leaf species in landscaping.

Management Activity 4: Conduct regular forest/vegetative and avian surveys
Strategy 1: Regularly schedule vegetative and avian surveys to establish baselines and track changes in vegetative and avian communities as a result of restoration efforts.

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# APPENDICES

**Appendix A.** Coordinates for 13 Transects Surveyed on U.S. Navy Support Facility Diego Garcia in November 2017.

| Station | Degrees, Decimal Minutes | | Decimal Degrees | | Notes |
|---|---|---|---|---|---|
| | Latitude | Longitude | Latitude | Longitude | |
| 1-1 | S 07°16.343' | E 72°21.498' | -7.272383 | 72.358300 | Water Wells along R-Site to C-Site Road, Cantonment |
| 1-2 | S 07°16.342' | E 72°21.498' | -7.272367 | 72.358300 | |
| 1-3 | S 07°16.360' | E 72°21.519' | -7.272667 | 72.358650 | |
| 1-4 | S 07°16.405' | E 72°21.525' | -7.273417 | 72.358750 | |
| 1-5 | S 07°16.436' | E 72°21.525' | -7.273933 | 72.358750 | |
| 1-6 | S 07°16.460' | E 72°21.544' | -7.274333 | 72.359067 | |
| 1-7 | S 07°16.492' | E 72°21.558' | -7.274867 | 72.359300 | |
| 1-8 | S 07°16.515' | E 72°21.582' | -7.275250 | 72.359700 | |
| 1-9 | S 07°16.543' | E 72°21.586' | -7.275717 | 72.359767 | |
| 1-10 | S 07°16.571' | E 72°21.611' | -7.276183 | 72.360183 | |
| 2-1 | S 07°16.316' | E 72°21.681' | -7.271933 | 72.361350 | Water Wells near ARTS/GPS (Det. 21, SOPS, USAF) |
| 2-2 | S 07°16.317' | E 72°21.684' | -7.271950 | 72.361400 | |
| 2-3 | S 07°16.330' | E 72°21.738' | -7.272167 | 72.362300 | |
| 2-4 | S 07°16.319' | E 72°21.763' | -7.271983 | 72.362717 | |
| 2-5 | S 07°16.318' | E 72°21.789' | -7.271967 | 72.363150 | |
| 3-1 | S 07°13.997' | E 72°26.084' | -7.233283 | 72.434733 | Barton Pt. |
| 3-2 | S 07°14.027' | E 72°26.082' | -7.233783 | 72.434700 | |
| 3-3 | S 07°14.050' | E 72°26.093' | -7.234167 | 72.434883 | |
| 3-4 | S 07°14.079' | E 72°26.103' | -7.234650 | 72.435050 | |
| 3-5 | S 07°14.101' | E 72°26.117' | -7.235017 | 72.435283 | |
| 4-1 | S 07°14.327' | E 72°26.127' | -7.238783 | 72.435450 | Barton Pt. near Navigational Aid (Lagoon Side) |
| 4-2 | S 07°14.327' | E 72°26.162' | -7.238783 | 72.436033 | |
| 4-3 | S 07°14.312' | E 72°26.185' | -7.238533 | 72.436417 | |
| 4-4 | S 07°14.293' | E 72°26.215' | -7.238217 | 72.436917 | |
| 4-5 | S 07°14.284' | E 72°26.250' | -7.238067 | 72.437500 | |
| 5-1 | S 07°19.055' | E 72°28.993' | -7.317583 | 72.483217 | Minni-Minni |
| 5-2 | S 07°19.096' | E 72°29.010' | -7.318267 | 72.483500 | |
| 5-3 | S 07°19.141' | E 72°28.968' | -7.319017 | 72.482800 | |
| 5-4 | S 07°19.197' | E 72°28.938' | -7.319950 | 72.482300 | |
| 5-5 | S 07°19.232' | E 72°28.886' | -7.320533 | 72.481433 | |
| 5-6 | S 07°19.281' | E 72°28.862' | -7.321350 | 72.481033 | |
| 5-7 | S 07°19.326' | E 72°28.824' | -7.322100 | 72.480400 | |
| 5-8 | S 07°19.364' | E 72°28.789' | -7.322733 | 72.479817 | |
| 5-9 | S 07°19.413' | E 72°28.722' | -7.323550 | 72.478700 | |
| 5-10 | S 07°19.440' | E 72°28.659' | -7.324000 | 72.477650 | |

| Station | Degrees, Decimal Minutes | | Decimal Degrees | | Notes |
|---|---|---|---|---|---|
| | Latitude | Longitude | Latitude | Longitude | |
| 6-1 | S 07°15.991' | E 72°27.440' | -7.266517 | 72.457333 | Cust Point |
| 6-2 | S 07°16.074' | E 72°27.486' | -7.267900 | 72.458100 | |
| 6-3 | S 07°16.099' | E 72°27.541' | -7.268317 | 72.459017 | |
| 6-4 | S 07°16.176' | E 72°27.570' | -7.269600 | 72.459500 | |
| 6-5 | S 07°16.212' | E 72°27.641' | -7.270200 | 72.460683 | |
| 6-6 | S 07°16.227' | E 72°27.700' | -7.270450 | 72.461667 | |
| 6-7 | S 07°16.239' | E 72°27.729' | -7.270650 | 72.462150 | |
| 6-8 | S 07°16.259' | E 72°27.744' | -7.270983 | 72.462400 | |
| 6-9 | S 07°16.294' | E 72°27.740' | -7.271567 | 72.462333 | |
| 6-10 | S 07°16.324' | E 72°27.754' | -7.272067 | 72.462567 | |
| 7-1 | S 07°20.812' | E 72°27.995' | -7.346867 | 72.466583 | Inside the Strict Nature Reserve at East Pt. Plantation |
| 7-2 | S 07°20.775' | E 72°28.008' | -7.346250 | 72.466800 | |
| 7-3 | S 07°20.743' | E 72°28.021' | -7.345717 | 72.467017 | |
| 7-4 | S 07°20.716' | E 72°28.027' | -7.345267 | 72.467117 | |
| 7-5 | S 07°20.685' | E 72°28.049' | -7.344750 | 72.467483 | |
| 7-6 | S 07°20.653' | E 72°28.063' | -7.344217 | 72.467717 | |
| 7-7 | S 07°20.633' | E 72°28.073' | -7.343883 | 72.467883 | |
| 7-8 | S 07°20.613' | E 72°28.102' | -7.343550 | 72.468367 | |
| 7-9 | S 07°20.597' | E 72°28.126' | -7.343283 | 72.468767 | |
| 7-10 | S 07°20.594' | E 72°28.146' | -7.343233 | 72.469100 | |
| 8-1 | S 07°24.607' | E 72°27.068' | -7.410117 | 72.451133 | GEODSS |
| 8-2 | S 07°24.628' | E 72°27.046' | -7.410467 | 72.450767 | |
| 8-3 | S 07°24.636' | E 72°27.025' | -7.410600 | 72.450417 | |
| 8-4 | S 07°24.664' | E 72°27.009' | -7.411067 | 72.450150 | |
| 8-5 | S 07°24.678' | E 72°26.988' | -7.411300 | 72.449800 | |
| 8-6 | S 07°24.698' | E 72°26.976' | -7.411633 | 72.449600 | |
| 8-7 | S 07°24.720' | E 72°26.959' | -7.412000 | 72.449317 | |
| 8-8 | S 07°24.745' | E 72°26.941' | -7.412417 | 72.449017 | |
| 8-9 | S 07°24.773' | E 72°26.935' | -7.412883 | 72.448917 | |
| 8-10 | S 07°24.793' | E 72°26.945' | -7.413217 | 72.449083 | |
| 9-1 | S 07°22.872' | E 72°29.523' | -7.381200 | 72.492050 | Horsburgh Pt. |
| 9-2 | S 07°22.840' | E 72°29.519' | -7.380667 | 72.491983 | |
| 9-3 | S 07°22.812' | E 72°29.514' | -7.380200 | 72.491900 | |
| 9-4 | S 07°22.780' | E 72°29.476' | -7.379667 | 72.491267 | |
| 9-5 | S 07°22.749' | E 72°29.474' | -7.379150 | 72.491233 | |
| 9-6 | S 07°22.724' | E 72°29.466' | -7.378733 | 72.491100 | |
| 9-7 | S 07°22.701' | E 72°29.459' | -7.378350 | 72.490983 | |
| 9-8 | S 07°22.899' | E 72°29.524' | -7.381650 | 72.492067 | |
| 9-9 | S 07°22.925' | E 72°29.523' | -7.382083 | 72.492050 | |
| 9-10 | S 07°22.944' | E 72°29.510' | -7.382400 | 72.491833 | |

| Station | Degrees, Decimal Minutes | | Decimal Degrees | | Notes |
|---|---|---|---|---|---|
| | Latitude | Longitude | Latitude | Longitude | |
| 10-1 | S 07°25.292' | E 72°25.278' | -7.421533 | 72.421300 | Along 14 mile Mark on Ocean Side |
| 10-2 | S 07°25.323' | E 72°25.285' | -7.422050 | 72.421417 | |
| 10-3 | S 07°25.345' | E 72°25.282' | -7.422417 | 72.421367 | |
| 10-4 | S 07°25.374' | E 72°25.281' | -7.422900 | 72.421350 | |
| 10-5 | S 07°25.402' | E 72°25.274' | -7.423367 | 72.421233 | |
| 10-6 | S 07°25.432' | E 72°25.277' | -7.423867 | 72.421283 | |
| 10-7 | S 07°25.458' | E 72°25.273' | -7.424300 | 72.421217 | |
| 10-8 | S 07°25.479' | E 72°25.275' | -7.424650 | 72.421250 | |
| 10-9 | S 07°25.502' | E 72°25.275' | -7.425033 | 72.421250 | |
| 10-10 | S 07°25.529' | E 72°25.274' | -7.425483 | 72.421233 | |
| 11-1 | S 07°21.742' | E 72°25.885' | -7.362367 | 72.431417 | Lagoon Side Between Landfill and Small Arms Storage Building |
| 11-2 | S 07°21.767' | E 72°25.880' | -7.362783 | 72.431333 | |
| 11-3 | S 07°21.795' | E 72°25.871' | -7.363250 | 72.431183 | |
| 11-4 | S 07°21.818' | E 72°25.868' | -7.363633 | 72.431133 | |
| 11-5 | S 07°21.847' | E 72°25.856' | -7.364117 | 72.430933 | |
| 11-6 | S 07°21.882' | E 72°25.847' | -7.364700 | 72.430783 | |
| 11-7 | S 07°21.929' | E 72°25.828' | -7.365483 | 72.430467 | |
| 11-8 | S 07°21.979' | E 72°25.820' | -7.366317 | 72.430333 | |
| 11-9 | S 07°22.028' | E 72°25.807' | -7.367133 | 72.430117 | |
| 11-10 | S 07°22.082' | E 72°25.789' | -7.368033 | 72.429817 | |
| 12-1 | S 07°14.856' | E 72°23.118' | -7.247600 | 72.385300 | East Island |
| 12-2 | S 07°14.866' | E 72°23.109' | -7.247767 | 72.385150 | |
| 12-3 | S 07°14.874' | E 72°23.095' | -7.247900 | 72.384917 | |
| 12-4 | S 07°14.895' | E 72°23.070' | -7.248250 | 72.384500 | |
| 13-1 | S 07°13.670' | E 72°24.978' | -7.227833 | 72.416300 | Middle Island |
| 13-2 | S 07°13.656' | E 72°25.025' | -7.227600 | 72.417083 | |
| 13-3 | S 07°13.654' | E 72°25.069' | -7.227567 | 72.417817 | |
| 13-4 | S 07°13.627' | E 72°25.107' | -7.227117 | 72.418450 | |
| 13-5 | S 07°13.610' | E 72°25.149' | -7.226833 | 72.419150 | |
| 13-6 | S 07°13.591' | E 72°25.181' | -7.226517 | 72.419683 | |
| 13-7 | S 07°13.571' | E 72°25.216' | -7.226183 | 72.420267 | |
| 13-8 | S 07°13.565' | E 72°25.258' | -7.226083 | 72.420967 | |
| 13-9 | S 07°13.570' | E 72°25.302' | -7.226167 | 72.421700 | |
| 13-10 | S 07°13.566' | E 72°25.350' | -7.226100 | 72.422500 | |

**Appendix B.** Google Earth Maps Showing On-the-Ground Location of Transects 1-13.


**Figure B.1**. Transect 1 (points 1-10) and transect 2 (points 1-5) surveyed on NSF Diego Garcia in November 2017. Points 1-1 and 1-2 are unique, though indistinguishable at pictured resolution.


**Figure B.2.** Transect 3 (points 1-5) and transect 4 (points 1-5) surveyed on NSF Diego Garcia in November 2017.

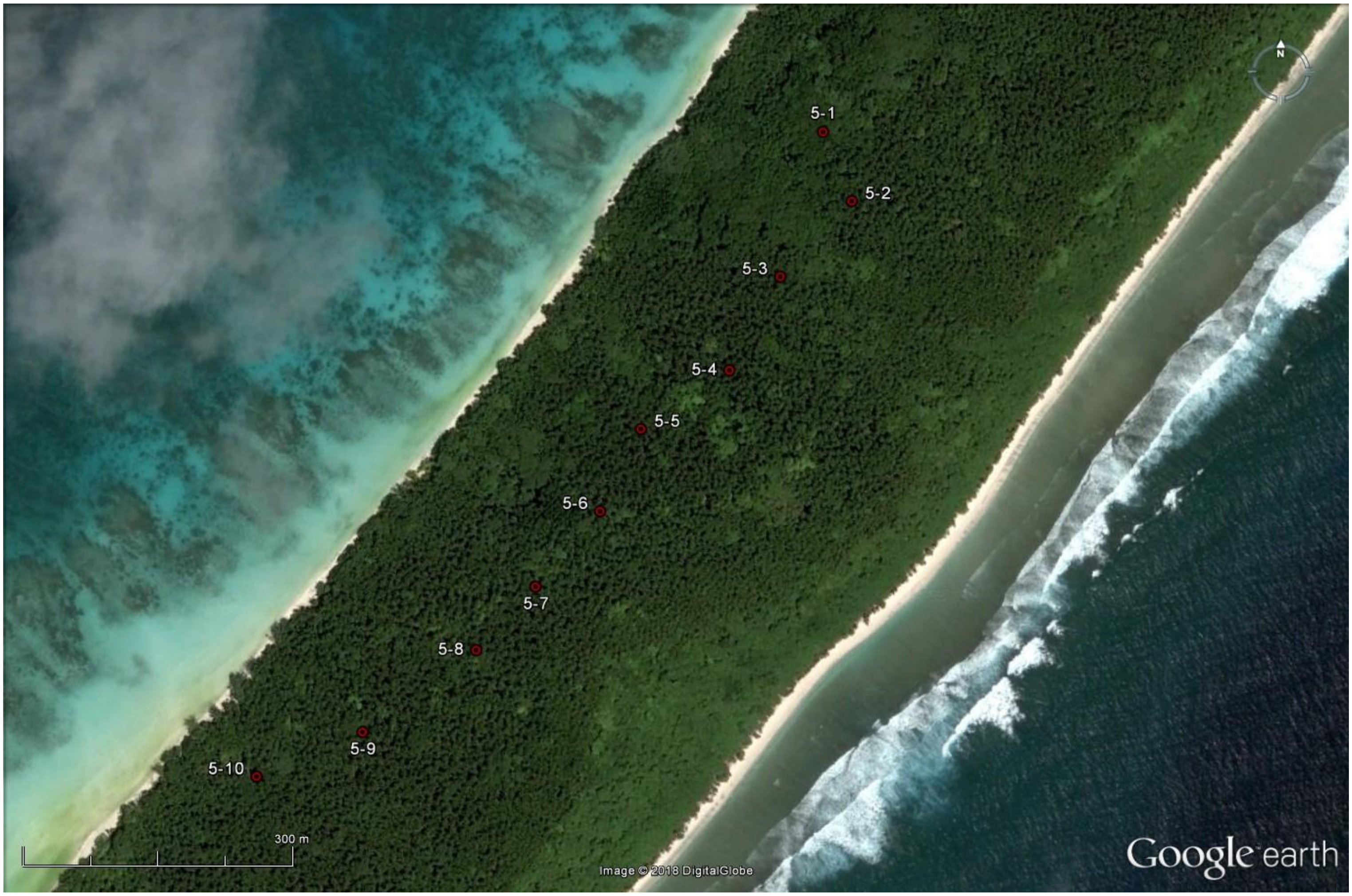


**Figure B.3.** Transect 5 (points 1-10) surveyed on NSF Diego Garcia in November 2017.


**Figure B.4**. Transect 6 (points 1-10) surveyed on NSF Diego Garcia in November 2017.


**Figure B.5.** Transect 7 (points 1-10) surveyed on NSF Diego Garcia in November 2017.


**Figure B.6.** Transect 8 (points 1-10) surveyed on NSF Diego Garcia in November 2017.

**Figure B.7.** Transect 9 (points 1-10) surveyed on NSF Diego Garcia in November 2017.


**Figure B.8.** Transect 10 (points 1-10) surveyed on NSF Diego Garcia in November 2017.


**Figure B.9.** Transect 11 (points 1-10) surveyed on NSF Diego Garcia in November 2017.


**Figure B.10.** Transect 12 (points 1-4) surveyed on NSF Diego Garcia in November 2017.

**Figure B.11.** Transect 13 (points 1-10) surveyed on NSF Diego Garcia in November 2017.

**Appendix C.** Common and Scientific Names of Trees Surveyed on NSF Diego Garcia, November 2017.

| Common Name(s) | Scientific Name |
|---|---|
| 1. Alexandrian Laurel/Taka Maka/ Kamani Tree | *Calophyllum inophyllum* |
| 2. Beach Gardenia | *Guettarda speciosa* |
| 3. Beach Heliotrope/Tree Heliotrope | *Tournefortia argentea* |
| 4. Chinese Lantern Tree | *Hernandia sonora* |
| 5. Coconut Tree | *Cocos nucifera* |
| 6. Devil's Claw/Pisonia | *Pisonia grandis* |
| 7. Fish-Poison Tree/Rose Tree | *Barringtonia asiatica* |
| 8. Ifil Tree/Borneo Teak/Intsia/Gayac | *Intsia bijuga* |
| 9. Indian Mulberry/Noni | *Morinda citrifolia* |
| 10. Ironwood Tree | *Casuarina equisitifolia* |
| 11. Kou/Cordia | *Cordia subcordata* |
| 12. Neisosperma | *Neisosperma oppositifolia* |
| 13. Pipturus | *Pipturus argenteus* |
| 14. Premna | *Premna serratifolia* |
| 15. Tropical Almond/False Kamani Tree | *Terminalia catappa* |

**Appendix D**. Canopy cover (overstory density) for all survey points on NSF Diego Garcia, November 2017.

| ***Transect*** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | ***Mean %*** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 96.9 | 95.8 | 86.5 | 95.8 | 93.8 | 96.9 | 93.8 | 94.8 | 93.8 | 84.4 | ***93.2*** |
| **2** | 88.6 | 90.6 | 93.8 | 82.3 | 95.8 | | | | | | ***90.2*** |
| **3** | 86.5 | 57.4 | 86.5 | 90.6 | 100 | | | | | | ***84.2*** |
| **4** | 86.5 | 87.5 | 88.6 | 96.9 | 96.9 | | | | | | ***91.3*** |
| **5** | 96.9 | 86.5 | 80.2 | 79.2 | 91.7 | 93.8 | 77.1 | 99.0 | 90.6 | 100 | ***89.5*** |
| **6** | 97.9 | 95.8 | 86.5 | 95.8 | 91.7 | 93.8 | 93.8 | 77.1 | 79.2 | 74.0 | ***88.6*** |
| **7** | 96.9 | 94.8 | 100 | 97.9 | 93.8 | 87.5 | 99.0 | 90.6 | 16.8 | 83.4 | ***86.1*** |
| **8** | 83.4 | 86.5 | 92.7 | 96.9 | 95.8 | 99.0 | 93.8 | 89.6 | 85.4 | 93.8 | ***91.7*** |
| **9** | 74.0 | 93.8 | 99.0 | 88.6 | 79.2 | 74.0 | 56.3 | 97.9 | 94.8 | 95.8 | ***85.3*** |
| **10** | 96.9 | 97.9 | 100 | 100 | 83.4 | 92.7 | 94.8 | 96.9 | 81.3 | 96.9 | ***94.1*** |
| **11** | 92.7 | 92.7 | 96.9 | 97.9 | 90.6 | 92.7 | 100 | 92.7 | 91.7 | 97.9 | ***94.6*** |
| ***12*** | 77.1 | 87.5 | 70.9 | 86.5 | | | | | | | ***80.5*** |
| ***13*** | 99.0 | 91.7 | 94.8 | 84.4 | 91.7 | 96.9 | 85.4 | 90.6 | 88.6 | 75.0 | ***89.8*** |

Mean canopy cover for all Transects combined (n=13) = 89.2%