NESTING PREFERENCES AND POPULATION ESTIMATES OF A NEW BLACK NODDY *ANOUS MINUTUS* BREEDING COLONY ON ONE TREE ISLAND, GREAT BARRIER REEF, AUSTRALIA

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SUMMARY

CÓRDOBA-CÓRDOBA, S., OUYANG, J.Q. & HAUCK, S.J. 2010. Nesting preferences and population estimates of a new Black Noddy *Anous minutus* breeding colony on One Tree Island, Great Barrier Reef, Australia. *Marine Ornithology* 38: 79–84.

Establishment of marine birds on islands is an important part of island biogeography, and the monitoring of new seabird populations is crucial to understanding habitat selection and population dynamics. The Black Noddy *Anous minutus,* a seabird that nests mainly on woody vegetation in large breeding colonies, has grown in population within the Great Barrier Reef (GBR) for the past half century and has established new resident and breeding colonies on many islands. Our aims were to census a recently established population of Black Noddies and to study their abiotic and biotic nesting preferences. We found that noddies did not nest on windy portions of the island and chose core, mid-height of plants as the preferred nesting position on the leeward side. There was no significant difference in Black Noddy nesting preference between the two dominant plant species *Pisonia grandis* and *Argusia argentea.* Of a population of approximately 2200 individuals, we estimated that as many as 1500 could have been breeding. Our study highlights the importance of looking at both macro- and micro-scales for individual nest selection. To understand the fluctuating population dynamics, we recommend active monitoring of seabird populations on several islands throughout the southern GBR.

Key words: *Anous minutus,* Black Noddy, breeding colony, nest preferences, One Tree Island, population size

RESUMEN

CÓRDOBA-CÓRDOBA, S., OUYANG, J.Q. & HAUCK, S.J. 2010. Sitios preferenciales para anidar y estimación poblacional de una nueva colonia reproductiva de la Tiñosa Común *Anous minutus* en la Isla One Tree Island en la Gran Barrera de Coral, Australia. *Marine Ornithology* 38: 79–84.

El establecimiento de aves marinas en islas es parte importante de la biogeografía de islas, asi mismo el monitoreo de nuevas poblaciones de aves marinas es crucial para entender selección de hábitat y dinámica de poblaciones. La Tiñosa Común *Anous minutus,* es un ave marina que anida principalmente sobre vegetación leñosa en grandes colonias reproductivas. Su población ha crecido en tamaño en la ultima mitad del siglo pasado en la Gran Barrera de Coral (Great Barrier Reef, Australia), estableciendo nuevas colonias de residencia y reproducción en muchas islas. Nuestros objetivos fueron censar una colonia reproductiva recientemente establecida de la Tiñosa, y estudiar factores abióticos y bióticos que influyen en las preferencias para anidar. Encontramos que la Tiñosa Común no anida en lugares con viento directo en la isla. Escoge la parte mas cercana al tronco y a media altura de las plantas leñosas como sitio preferido para anidar, y solo en partes sin viento constante de la isla. No encontramos diferencias significativas en la preferencia por anidar entre las dos plantas leñosas dominantes de la isla *Pisonia grandis* y *Argusia argentea.* Estimamos aproximadamente 2200 individuos en la isla, de los cuales 1500 podrían estar reproduciéndose. Nuestro estudio destaca la importancia de estudiar la selección de anidación tanto a macro (la isla) como a micro-escalas. Para entender la dinámica de las fluctuaciones poblacionales, recomendamos el monitoreo activo de poblaciones de aves marinas en varias islas a lo largo de la parte sur de la Gran Barrera de Coral.

Palabras clave: *Anous minutus,* colonia de anidación, preferencias de anidación, Tiñosa Común, One Tree Island, tamaño poblacional

INTRODUCTION

Establishment of populations on islands is an essential part of island biogeography and population dynamics (Schreiber & Burger 2002). Marine birds, in particular, may become established on an island because of food and habitat availability as well as nest-site characteristics (Hamer *et al.* 2002). Habitat selection for colonial marine birds may be influenced by environmental factors (wind speed, temperature and sun exposure), social factors (aggressiveness of neighbors and presence of conspecifics) and predation pressures (Burger & Gochfeld 1985, Hamer *et al.* 2002). Nesting habitats are then chosen for specific site characteristics and requirements, such as nesting material, plant species, plant height and plant cover (Burger & Gochfeld 1985, Hamer *et al.* 2002). However, nesting preferences for many seabird species have not been closely examined.

Black Noddies *Anous minutus* are colonial nesters and surface-feeders that tend to forage close to shore (del Hoyo *et al.* 1996, Gauger 1999). They are found mainly on oceanic and offshore islands in the tropical waters of the Pacific and Atlantic Oceans (del Hoyo *et al.* 1996). Successful breeding depends on finding suitable islands with trees and bushes to nest on (del Hoyo *et al.* 1996). Population estimates for several islands within the southern Great Barrier Reef (GBR) show that *A. minutus* is one of the most abundant species and that the southern GBR is one of its most important breeding areas (Dyer *et al.* 2005). Population estimates for Heron Island show that the population of Black Noddies has increased since the middle of the last century (Ogden 1993a, Dyer *et al.* 2005). Although Black Noddies have been studied on several islands, they were not known to breed on One Tree Island (OTI) (19 km from Heron Island) earlier than 1980 (Domm & Recher 1973, Langham 1986). Hence, their establishment on OTI provides an opportunity to understand how nesting preferences may evolve in a recently formed colony.

Nest selection on individual trees or particular plant species has important implications for Noddy reproductive success. For example, breeding pairs are affected by environmental factors (cyclones, rain and wind) (Langham 1986, Ogden 1993b, Hulsman *et al.* 1997) and predation (Braithwaite 1973, Langham 1986, Congdon 1991). Although many studies have looked at Noddy nesting preferences for particular species of plants, no one to our knowledge has characterized nest selection among individual plants. Furthermore, Noddies nest on many different species of plants, but the reason for their preference for some plants over others is unclear. *Celtis paniculata* and *Ficus opposita* are preferred over *Pisonia grandis* although the latter is the most abundant tree species on many islands where Black Noddies nest (Jahnke 1975, Hulsman *et al.* 1984). Other plant species such as *Argusia argentea* are rarely, if ever, used by Black Noddies (Braithwaite 1973, Dale *et al.* 1984, Hulsman *et al.* 1984, Barnes & Hill 1989). On OTI however, *P. grandis* and *A. argentea* are the most common species available for nesting Noddies. *P. grandis* is a shade-intolerant tree that grows mainly on islands and, because of its brittle wood and branches prone to damage by storms and cyclones, in areas protected from prevailing winds. In such areas, it may form dense stands and a closed canopy (Cribb 1969, Heatwole *et al.* 1981, Walker 1991). *A. argentea* is a woody halophytic shrub that grows on islands, usually close to the water line, and generally on beaches, forming a peripheral line of vegetation on islands (Heatwole *et al.* 1981, McDonald 2005).

Since Black Noddies have recently established a breeding population on OTI, they provide an ideal opportunity to study a population small enough to record data for a high proportion of the breeding birds in order to determine their nesting preferences. The goals of this study were: (1) to determine whether Black Noddies select the leeward or windward sides of the island to breed; (2) to describe nest-site characteristics for an incipient breeding colony; (3) to compare nest-site selection for different woody plant species; and (4) to estimate population and breeding numbers for One Tree Island.

STUDY AREA

One Tree Island (23°31′S, 152°06′E) is in the Capricorn Group Section at the southern end of the Great Barrier Reef, Australia (Heatwole *et al.* 1981, see Figure 1). It is 80 km east of the mainland, and its nearest neighbor is Heron Island (Heatwole *et al.* 1981). It is located on the southeast corner of the One Tree Reef, where it is exposed to prevailing winds, with the southern corner receiving direct southeasterly winds (Heatwole *et al.* 1981). The 4.93 ha island is a shingle coral cay of coarse coralline rubble with scattered vegetation and almost no sand (Domm & Recher 1973, Flood 1977, Heatwole *et al.* 1981). The island has five main pockets of woody vegetation composed of *Pisonia, Argusia* and *Pandanus* spp. All woody plant patches of *Pisonia* and *Pandanus* are below 5 m in height, which is smaller than woody plants of other surrounding islands. Several seabirds breed on the island, including 6 species of terns and the silver gull (Domm & Recher 1973, Hulsman 1973, 1974, 1977, Heatwole *et al.* 1981).

METHODS

We studied Noddy habitat selection by evaluating nest placement on woody plants on the northern and southern parts of the island, where it was possible to conduct research without disturbing other breeding seabirds. The northern part of the island (leeward, where the research station was located) is more protected from winds, whereas the southern part faces direct prevailing winds. At the leeward site, *A. argentea* and *P. grandis* plants were randomly sampled along the research station trails; at the windward site, plants were sampled along the coastline starting from the middle southwest of the island and proceeding toward the southern tip. On the leeward side, both plant species were found and sampled, but only *Argusia* shrubs were sampled on the windward side.

Data were collected in January 2008. For each *Pisonia* and *Argusia* plant sampled, the following were recorded: presence of nests, plant species, total height and plant diameter (measured with a diameter tape just above the basal root expansion and below the multiple trunk divergence). All Black Noddy nests found in a plant were recorded and used in the analysis. For each nest, vertical position

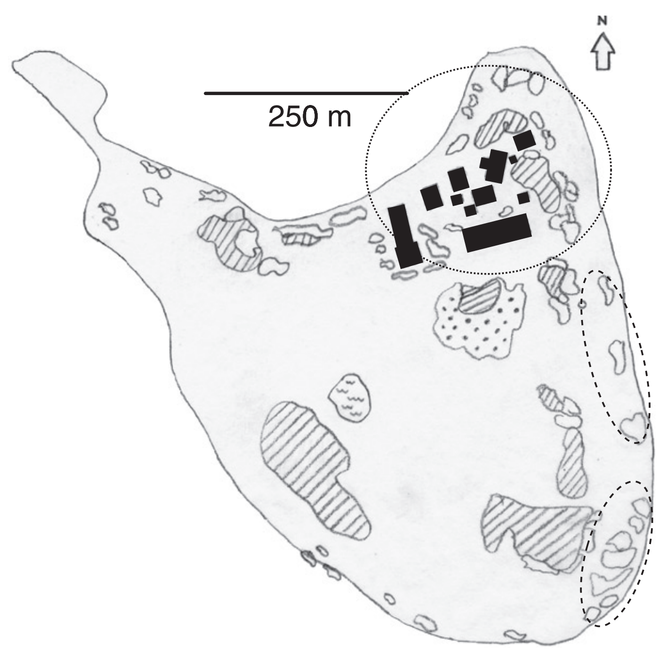

Fig. 1. Map of study site and vegetation zones of One Tree Island. Hatched areas indicate *Pisonia* groves, areas of large dots a *Pandanus* grove, and open outline *Argusia* shrubs. Shaded rectangles are buildings. Finely dashed circle indicates the leeward study site and thick dashed lined circles indicate the windward study sites (modified from Heatwole *et al.* 1981).

(in centimeters above ground) was recorded. We normalized vertical nest position (nest height/plant height) because relative nest placement within the vegetation is more important than nest height alone. Horizontal position was also recorded as the distance from the center of the plant. It was categorized as "core" (from trunk to 1/3 of the canopy radius), "intermediate" (1/3 to 2/3 of the canopy radius from trunk) or "exterior" (2/3 to outermost part of the canopy radius).

Relationships between plant characteristics and nests were explored using Pearson's correlation coefficient and simple linear regression analysis. Differences in nest position, normalized plant height and nest dimension between the two plant species were analyzed using Kruskal-Wallis analysis of variance (K-W test) (Siegel & Castellan 1988).

To estimate populations of Black Noddies, we performed an independent census of all roosting adult birds, juveniles, chicks and eggs on all shrubs and trees near the research station. We estimated total surface area of woody vegetation where birds were nesting or roosting or both. The surveyed area included pockets of *Pisonia* trees and most vegetation on the northern part of the island, and excluded the *Pandanus* grove and *Argusia* plants on the eastern and southern part of the island, where no nests were recorded. Woody area was estimated for 2008 by field-checking the current vegetation boundaries with the most recently published map: *Great Barrier Reef Mapping Capricorn Section Sheet DA, One Tree Island, Queensland 1:2500* (1982). We obtained a rough estimate of the density of birds per square meter of woody vegetation from the census, which was extrapolated to the total area of occupied woody vegetation. The breeding population, counted as breeding adult pairs, was independently estimated from the number of active nests found in the census, each containing a juvenile, chick or egg.

RESULTS

We found that Noddies not only preferentially nested in different locations on an island, but also selected different locations within a plant. Our study shows for the first time the importance of examining nest-site selection within individual plants, rather than nest-site selection for particular plant species.

Windward vs. leeward island nest placement

We found no nests on the windward part of the island (*Argusia* was the only available plant, n = 37). On the leeward part, near the research station, Black Noddy nests were found on 29% of the *Argusia* plants randomly sampled (n = 21) and on 66.7% of the *Pisonia* plants sampled (n = 24).

At the leeward site, where plants are protected from direct prevailing winds, plant height has a positive linear relationship with basal diameter, and plants are characterized by proportional growth. By contrast, at the windy southern site, plant height has a log-linear relationship with basal diameter; plants are stunted, with larger basal diameters in proportion to plant height (leeward linear $R^2 = 0.73$, $F_{1,53} = 144.67$, $P < 0.0001$; windward log-linear $R^2 = 0.67$, $F_{1,35} = 75.10$, $P < 0.0001$) (Fig. 2).

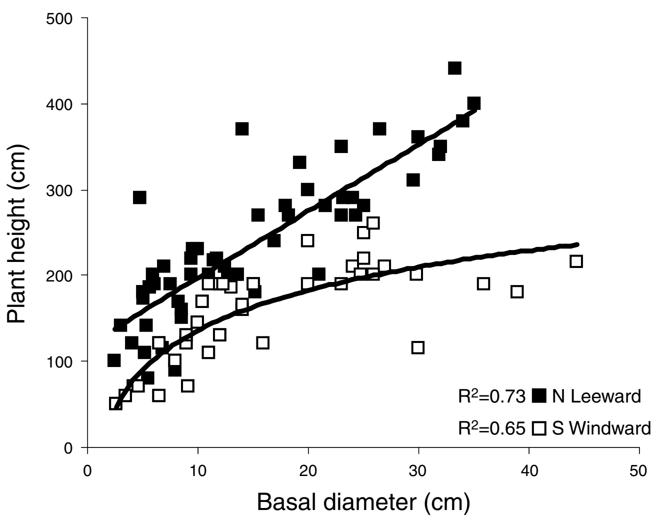

Fig. 2. Plant height and basal diameter for both *Argusia* and *Pisonia* plants on the leeward and windward sides of the island. Lines reflect regression scores for each location: leeward site is best represented by a linear regression line and windward site is best represented by a log-linear regression line.

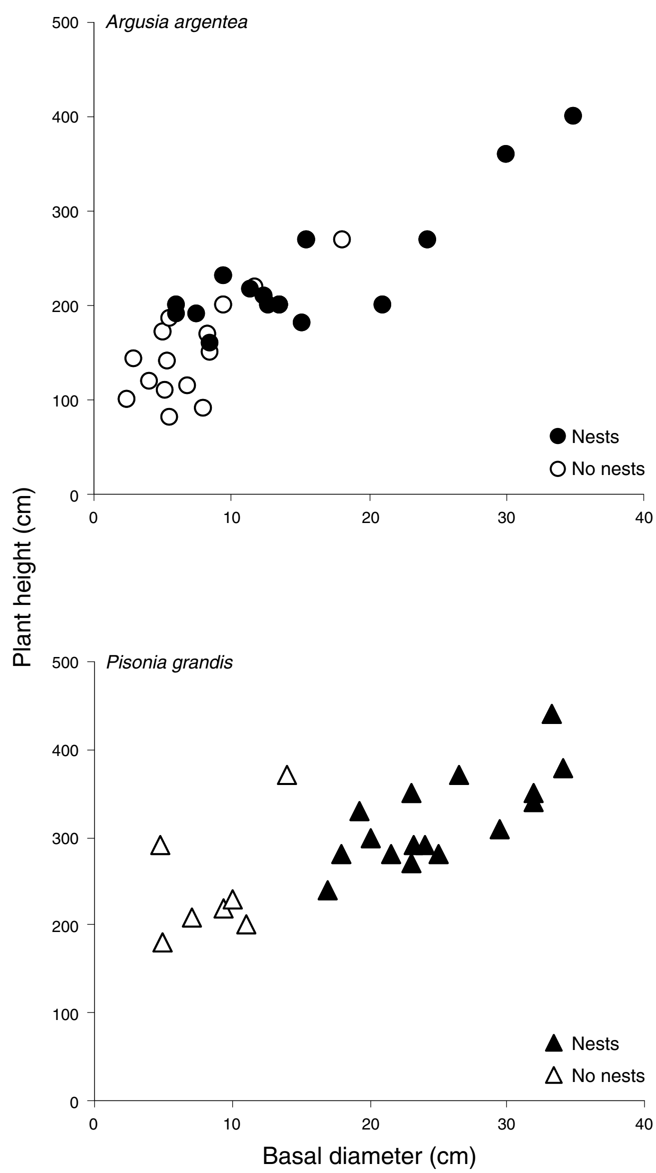

Fig. 3. Nest presence on *Argusia* and *Pisonia* plants in relation to plant height and basal diameter.

Nest placement and vegetation

The only plants with nests were found on the leeward side of the island. Noddies placed nests on larger plants, but not all available tall plants had nests. Of the plants sampled (n = 55), 58% had at least one nest (31 *Argusia,* 16 with nests; 24 *Pisonia,* 16 with nests). The average height of woody plants sampled was 191.7 cm ± 12.8 cm (standard error) (n = 31 *Argusia*) and 290.8 cm ± 13.8 cm (standard error) (n = 24 *Pisonia*). Nests were found only on plants above 160 cm, and the highest plant recorded reached 440 cm (Fig. 3).

Noddies selectively nested at distinct vertical zones, which were similar for both plant species. Noddies placed nests in *Argusia* shrubs at heights greater than 160 cm, but placed nests in *Pisonia* plants only at heights greater than 240 cm (Fig. 3). Black Noddies placed their nests at the same average height in both plant species (K-W $test_1$ = 1.63, $P > 0.20$, *Argusia* nests = 283, *Pisonia* nests = 168). Vertical nest position for both plants was around the average normalized nest height of 0.56. Also, 91% of the nests recorded (n = 451 in 32 plants) were placed at a normalized nest height between 0.28 and 0.82, indicating that breeding pairs tend to avoid near-ground or very high canopy exposure.

Horizontal nest position differed among the core (C), intermediate (I) and exterior (E) parts of the woody plants studied when accounting for normalized nest height (K-W $test_2$ = 46.65, $P <$ 0.001, $n_C = 110$, $n_I = 123$, $n_E = 218$). Nests were placed significantly higher in the core area than in the exterior area of both plant species. However, for *Pisonia,* nests were placed at relatively the same height for intermediate and exterior horizontal positions (Table 1), possibly reflecting differences in plant branching architecture.

Plant species and Noddy nests

Although we found nests at all available heights, Noddies tended to place nests toward the core of the plant (Fig. 4). When only a few nests were found in a plant, they were preferentially placed toward the core of the plant, and this was true for both species. As more nests were placed, they filled up the higher portions of the plant, excluding the upper extreme. Nest placement in the lower portion of the plant differed between species: in *Pisonia,* as more nests were placed, the lower height was filled slowly from the average normalized nest height toward the ground until 70% of the plant height had at least one nest. In *Argusia* plants, the lower half was filled even when there were very few nests on the plant, but the lowest portions of the plant were not used until almost 90% of the plant height had at least one nest.

TABLE 1
Horizontal position of Black Noddy *Anous minutus* nests on two plant species

Plant species	Horizontal nest position, average normalized nest height ± SE: Core	Intermediate	Exterior	Kruskal-Wallis test
Argusia argentea	0.66 ± 0.016 (n = 68)	0.62 ± 0.015 (n = 75)	0.49 ± 0.014 (n = 140)	50.3, P < 0.001
Pisonia grandis	0.60 ± 0.024 (n = 42)	0.53 ± 0.021 (n = 48)	0.53 ± 0.018 (n = 78)	6.21, 0.2 < P < 0.5

The total number of nests found in each plant species differed with the size of the plant (*Argusia* $R = 0.85$; $F_{1,14} = 32.39$, $P < 0.0001$; *Pisonia* $R = 0.67$; $F_{1,14} = 11.60$, $P < 0.004$). For *Argusia,* the number of nests present is a linear function of plant height: number of nests on *Argusia* = (0.326 × plant height) – 59.8; whereas for *Pisonia* the linear equation is: number of nests on *Pisonia* = (0.134 × plant height) – 32.96. These differences again reflect plant branching height and architecture more than plant species.

Population and breeding population estimates

The Black Noddy census in the northern part of the island included 402 adults in an area of approximately 5400 m^2, for an adult density of 0.074 birds per m^2, as well as 45 juveniles, 34 chicks and 56 eggs. We estimated the island had 30 000 m^2 of total woody vegetation that could be used by the Noddies (excluding the windward *Argusia* shrubs and *Pandanus* grove). Extrapolating from the northern adult density, we estimated that as many as 2200 adult individuals could be found on the island. Taking as an estimate of adult breeding pairs those that produced a juvenile, chick and egg from the northern census, we extrapolated that the total island could have around 1500 breeding adult birds.

DISCUSSION

The breeding of *A. minutus* on One Tree Island is a recent phenomenon, although breeding colonies have been recorded for the southern Capricorn Cays since the early 20th century (MacGillivray 1926). Noddies are a marine species that has successfully expanded not only its range but also its breeding populations to new islands, and its habitat preferences may have facilitated this expansion. Understanding how seabirds colonize islands is important because islands are limited and crucial to their survival, particularly if the ranges of seabirds shift in the face of predicted large-scale environmental change. In this study, we demonstrate undocumented trends in the nest selection of a newly established Black Noddy population.

Windward vs. leeward island nest placement

Black Noddies nested in different locations on the island. They did not nest in the windy southeast of the island, or in any area exposed to direct prevailing winds. This may be owing to Black Noddies' inability to construct or adequately maintain a nest in windy conditions. Although Hulsman *et al.* (1984) did not find a location

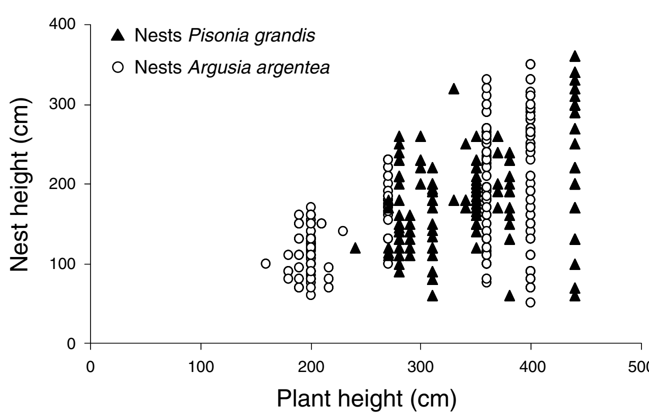

Fig. 4. Nest height in relation to plant height for *Argusia* and *Pisonia* plant species.

effect on nest distribution at Masthead Island, they did report a trend for an increasing number of nests from the windward to the leeward side. On Heron Island, the average number of nests per plant is higher for the western half of the island than for the eastern half (Barnes & Hill 1989). This indicates that the protected center and west-leeward sides are preferred by Noddies and can sustain higher nesting densities per plant than the exposed east-windward sides (Barnes & Hill 1989). In our study, this trend is even more pronounced in that no nests were found in the wind-exposed areas; Noddies may not nest in the windward parts because of the strong winds or because of a lack of suitable woody vegetation or plant species (*Argusia* is present but *Pisonia* is lacking).

Plant species and Noddy nests

Black Noddies are known to nest on *Pisonia* as well as *Ficus opposita* and *Celtis paniculata* (MacGillivray 1928, Jahnke 1975, Hulsman *et al.* 1984, Barnes & Hill 1989). Only occasionally have nests been recorded in *Argusia* (Hulsman *et al.* 1984); thus, it does not seem to be a preferred species (Hulsman *et al.* 1984). However, in our study, we found no selection for *Pisonia* over *Argusia* for nesting ($P > 0.20$). This may be due to the lack of other available nesting locations, since successional *Pisonia* trees are still being established on OTI, or to Noddies selecting for preferable plant architecture, given the options available, rather than for plant species.

Although Noddies show no plant species preference for nesting in our study, they may still rely on *Pisonia* plants when they are available (Cribb 1969, Walker 1991) because their leaves are an important resource for nest building (MacGillivray 1928, Gauger 1999). To our knowledge, no one has looked at the materials that make up a Noddy's nest, and it would be interesting to see whether *Pisonia* leaves are necessary for nesting, as other available material could also be used.

Nest placement and preferences for vegetation characteristics

Black Noddy nests were placed only on particular plants, depending on size and plant architecture. Small plants most likely did not have nests because they cannot support them; however, we found that on OTI Noddies nested lower on plants than they do on other islands. On Heron Island, nests were placed higher on plants, with the lowest nest recorded 120 cm from ground (Braithwaite 1973). This could be because of the relatively new establishment of vegetation on OTI or because plants are small and stunted due to a lack of soil and of supportive substrate on the coral island (Heatwole *et al.* 1981).

We found that average plant height is an important factor in nest selection; the largest number of nests was found on the tallest plants (tallest plant was 440 cm). Hulsman *et al.* (1984) have suggested that mean height of a plant is related to finding nests on it, but not necessarily related to the mean number of nests per plant. However, the number of nests is positively correlated with plant height (Ogden 1979, 1993a, Hulsman *et al.* 1984, Barnes & Hill 1989), with more nests being found at increasing height until a height threshold at which the tallest plants do not contain more nests than the smaller plants do (Ogden 1993a). We found that Noddies placed their nests mainly at an average normalized nest height of 0.56, toward the core parts of plants. Nests may be placed towards the core of the plant to avoid aggressive interactions with neighbors and interference from other individuals (Hulsman *et al.* 1984, Fisk 1977). Nesting preferences may also depend on plant height and general plant architecture, such as angle and density of branching, branch size and vertical and horizontal branching pattern. In addition, the sticky fruit clusters in the upper and outside parts of *Pisonia* plants may be avoided by nesting birds, since chicks may become entangled and die (Ogden 1993a). Although these factors have been suggested to influence nest selection, there has been no evidence to suggest that marine birds preferentially select for core areas of plants. Our study provides support for these theories because we found consistent selection for particular locations within a plant despite plant species differences.

CONCLUSIONS

We found that Black Noddies are able to successfully colonize new islands with low vegetation such as OTI, and this adaptability may influence their population growth rates. Research is needed to understand their establishment and recruitment patterns, the origin of first-time breeders, and any changes in breeding locations (Hulsman *et al.* 1997).

We found clear evidence that Noddies nest in different areas of the island and on plants protected from wind, independent of plant species. Our study shows the relative importance of looking at both macro- and micro-scales when considering nest preferences. At a macro-level, prevalent wind is an abiotic condition that may severally limit available nesting habitat. At a micro-level, individual characteristics within a plant are more important for Noddies than particular plant species. We demonstrate that nests fill a suitable plant in a non-random pattern, filling the intermediate portion of the plant first and then expanding toward the exterior portions. This pattern may be established by adults to avoid wind, cyclones, unwanted social interactions or predators.

A systematic census, even on a short visit, is useful as a basis for looking at longer-term population dynamics. Detailed population censuses of active breeding populations are not currently available for many islands in the GBR; such censuses would help to achieve a better understanding of not only the breeding ecology of the birds, but also when and why fluctuations occur (Dyer *et al.* 2005). Both widespread seabirds as well as those restricted to a small area can help us monitor changes at global and local scales as they are presented with many natural and anthropogenic threats (Croxall *et al.* 1984, reviewed in Hulsman *et al.* 1997 and Boere *et al.* 2006).

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REFERENCES

BARNES, A. & HILL, G.J.E. 1989. Census and distribution of Black Noddy *Anous minutus* nests on Heron Island, November 1985. *Emu* 89: 129–134.

BRAITHWAITE, R.W. 1973. Nesting habits of White-Capped Noddies. *Sunbird* 4: 1–4.

BURGER, J. & GOCHFELD, M. 1985. Nest site selection by laughing gulls: comparison of tropical colonies (Culebra, Puerto Rico) with temperate colonies (New Jersey). *Condor* 87: 364–373.

BOERE, G., GALBRAITH, C. & STROUD, D. (Eds). 2006. Waterbirds around the world. Edinburgh, UK: The Stationery Office.

CONGDON, B.C. 1991. Parent-offspring recognition in the Black Noddy *Anous minutus. Emu* 91: 158–163.

CRIBB, A.B. 1969. The Pisonia. *Queensland Naturalist* 19: 110–114.

CROXALL, J.P., EVANS, P.G.H. & SCHREIBER, R.W. 1984. The status and conservation of the world's seabirds. ICBP Technical Publication No. 2. Cambridge, UK: ICBP.

DALE, P., HULSMAN, K., JAHNKE, B.R. & DALE, M. 1984. Vegetation and nesting preferences of black noddies at Masthead Island, Great Barrier Reef. I. Patterns at the macro-scale. *Australian Journal of Ecology* 9: 335–341.

DEL HOYO, J., ELLIOT, A. & SARGATAL, J. 1996. Handbook of the birds of the world. Vol. 3. Hoatzin to Auks. Barcelona, Spain: Lynx Editions.

DOMM, S. & RECHER, H.F. 1973. The birds of One Tree Island with notes on their yearly cycle and feeding ecology. *Sunbird* 4: 63–86.

DYER, P.K., O'NEILL, P. & HULSMAN, K. 2005. Breeding numbers and population trends of Wedge-tailed Shearwater (*Puffinus pacificus*) and Black Noddy (*Anous minutus*) in the Capricornia Cays, southern Great Barrier Reef. *Emu* 105: 249–257.

FISK, P. 1977. Pair formation and related behavior in the white-capped noddy. *Sunbird* 8: 45–61.

FLOOD, P.G. 1977. Coral cays of the Capricorn and Bunker Groups, Great Barrier Reef Province, Australia. *Atoll Research Bulletin* 195: 1–23.

GAUGER, V.H. 1999. Black Noddy (*Anous minutus*). In Poole, A. (Ed). The Birds of North America online. Ithaca, NY: Cornell Lab of Ornithology. [Available online at: http://bna.birds.cornell.edu/bna/species/412. doi:bna.412; accessed 31 January 2008

HAMER, K.C., SCHREIBER, E.A. & BURGER, J. 2002. Breeding biology, life histories, and life history-environment interactions in seabirds. In Schreiber, E.A. & Burger, J. (Eds). Biology of marine birds. USA: CRC Press LLC. pp. 217–261.

HEATWOLE, H., DONE, T. & CAMERON, E. 1981. Community ecology of a coral cay: a study of One Tree Island, Great Barrier Reef, Australia. Monographs in Biology Vol. 43. The Hague: Junk.

HULSMAN, K. 1973. Addendum. (to The birds of One Tree Island with notes on their yearly cycle and feeding ecology by Domm and Recher). *Sunbird* 4: 86.

HULSMAN, K. 1974. Notes on the behavior of terns at One Tree Island. *Sunbird* 5: 44–49.

HULSMAN, K. 1977. Breeding success and mortality of terns at One Tree Island, Great Barrier Reef. *Emu* 77: 49–60.

HULSMAN, K., DALE, P. & JAHNKE, B.R. 1984. Vegetation and nesting preferences of black noddies at Masthead Island, Great Barrier Reef. II Patterns at the micro-scale. *Australian Journal of Ecology* 9: 343–352.

HULSMAN, K., O'NEILL, P., STOKES, T. & WARNETT, M. 1997. Threats, status, trends and management of seabirds on the Great Barrier Reef. In Reef Research Centre and Great Barrier Reef Marine Park Authority (Eds). The Great Barrier Reef: science, use and management, a national conference: proceedings. Townsville, Australia: Townsville CRC. Volume 1, pp.164–177.

JAHNKE, B.R. 1975. Population studies of some bird species on Masthead Island, Queensland. *Queensland Naturalist* 21: 67–73.

LANGHAM, N. 1986. The effect of cyclone 'Simon' on terns nesting on One Tree Island, Great Barrier Reef, Australia. *Emu* 86: 53–57.

MACGILLIVRAY, W. 1926. Birds of the Capricorn Islands. *Emu* 25: 229–238.

MACGILLIVRAY, W. 1928. Bird-life of the Bunker and Capricorn Islands. *Emu* 27: 230–249.

MCDONALD, R.J. 2005. Reproductive ecology and re-establishment of *Argusia argentea* on Ashmore Reef. *The Beagle Supplement* 1: 153–162.

OGDEN, J. 1979. Estimates of the population sizes of the Black Noddy and Wedge-tailed Shearwater at Heron Island in 1978. *Sunbird* 10: 33–39.

OGDEN, J. 1993a. Population increase and nesting patterns of the black noddy *Anous minutus* in *Pisonia* forest on Heron Island: observations in 1978, 1979 and 1992. *Australian Journal of Ecology* 18: 395–403.

OGDEN, J. 1993b. On cyclones, *Pisonia grandis* and the mortality of Black Noddy *Anous minutus* on Heron Island. *Emu* 93: 281–283.

QUEENSLAND DEPARTMENT OF MAPPING AND SURVEYING. 1982. Great Barrier Reef Mapping, Capricorn Section, Sheet DA, One Tree Island, Queensland, Scale 1:2500. Cartographic material. Brisbane, Australia: Sunmap.

SCHREIBER, E.A. & BURGER, J. (Eds). 2002. Biology of marine birds. USA: CRC Press LLC.

SIEGEL, S. & CASTELLAN JR., N.J. 1988. Non parametric statistics for the behavioral sciences. Second Edition. Boston, Mass.: McGraw-Hill Inc.

WALKER, T.A. 1991. Pisonia islands of the Great Barrier Reef. Part I. The distribution, abundance and dispersal by seabirds of *Pisonia grandis. Atoll Research Bulletin* 350: 1–23.