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The marine avifauna of Matthew and Hunter Islands, two remote volcanoes of the New Hebrides chain

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Abstract

The marine avifauna of Matthew and Hunter Islands, two remote volcanoes of the New Hebrides chain. Breeding birds recorded on Matthew and Hunter Islands in the tropical southwestern Pacific between 1973 and 2018 are summarised from a compilation of reports, for which various methods were used for counting seabirds. These methods included line transects, or direct observations using telescope or binoculars, or exhaustive counts, depending on the species observed and its nesting habitat. Population size estimates and reproductive periods are given. The total number of seabird species recorded breeding on the two islands was n = 14. This total includes seabird species breeding on both islands (n = 7): black–winged petrel *Pterodroma nigripennis*, wedge–tailed shearwater *Ardenna pacifica*, red–tailed tropicbird *Phaethon rubricauda*, masked booby *Sula dactylatra*, brown booby *S. leucogaster*, brown noddy *Anous stolidus*, and grey noddy *A. albivitta*. Hunter island also harbours a small colony of Herald petrel *Pterodroma heraldica*, and colonies of lesser and great frigatebirds (*Fregata ariel* and *F. minor*), red–footed booby *S. sula* and, black noddy *A. minutus* and white tern *Gygis alba*. Matthew Island harbours a large colony of sooty tern *Onychoprion fuscatus*; an undetermined storm petrel may also breed there. Differences between the two islands regarding community composition of seabirds are explained by the absence of trees on Matthew Island and the presence of the Polynesian rat *Rattus exulans* on Hunter Island. Brown noddies bred exclusively during the austral summer, as did black–winged petrels and wedge–tailed shearwaters, while the Herald petrel and the two frigatebirds seemed to preferentially breed in the winter. The red–tailed tropicbird, the three boobies, the grey noddy and the sooty tern appeared to reproduce year–round. Disturbance caused by human activities was irregular but devastating to seabird colonies. The diversity and abundance of seabird species breeding on these islands makes them regionally important sites for conservation.

Key words: Seabird, Population, Reproduction, Threats, Polynesian rat, Helicopters

Resumen

Avifauna marina de las islas Matthew y Hunter, dos volcanes remotos de la cadena de las Nuevas Hébridas. Las aves reproductoras registradas en las islas Matthew y Hunter, en el Pacífico suroccidental tropical, entre 1973 y 2018, se resumen a partir de una recopilación

de informes en los que se utilizaron diferentes métodos de recuento de aves marinas. Dichos métodos incluyeron transectos lineales, observaciones directas con telescopio o prismáticos y recuentos exhaustivos, dependiendo de la especie observada y su hábitat de anidación. Se dan estimaciones del tamaño de las poblaciones y de los periodos reproductivos. El número total de especies de aves marinas reproductoras registradas en las dos islas fue n = 14. Esta cifra total incluye las especies de aves marinas que se reproducen en ambas islas (n = 7): petrel alinegro *Pterodroma nigripennis*, pardela del Pacífico *Ardenna pacifica*, faetón colirrojo *Phaethon rubricauda*, piquero enmascarado *Sula dactylatra*, piquero pardo *Sula leucogaster*, tiñosa común *Anous stolidus* y tiñosa gris *Anous albivitta*. La isla Hunter también alberga una pequeña colonia de petrel heráldico *Pterodroma heraldica* y colonias de rabihorcado chico y rabihorcado grande *Fregata ariel* y *Fregata minor* y de piquero patirrojo *Sula sula*, así como de tiñosa menuda *Anous minutus* y de charrán blanco *Gygis alba*. En la isla Matthew existe una gran colonia de charrán sombrío *Onychoprion fuscatus* y es posible que en ella también se reproduzca un petrel de las tormentas indeterminado. Las diferencias en la composición de la comunidad de aves marinas entre las dos islas se explican por la ausencia de árboles en la isla Matthew y la presencia de la rata de Polinesia *Rattus exulans* en la isla Hunter. Las tiñosas comunes se reproducen exclusivamente durante el verano austral, al igual que los petreles alinegros y las pardelas del Pacífico, mientras que el petrel heráldico y los dos rabihorcados parecen reproducirse preferentemente en invierno. El faetón colirrojo, los tres piqueros, la tiñosa gris y el charrán sombrío parecen reproducirse durante todo el año. Las perturbaciones causadas por las actividades humanas han sido irregulares pero devastadoras para las colonias de aves marinas. La diversidad y abundancia de especies de aves marinas que se reproducen en estas islas las convierten en puntos de importancia regional para la conservación.

Palabras clave: Ave marina, Población, Reproducción, Amenazas, Rata de la Polinesia, Helicópteros

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Resum

Avifauna marina de les illes Matthew i Hunter, dos volcans remots de la cadena de les Noves Hèbrides. Els ocells reproductors registrats a les illes Matthew i Hunter, al Pacífic sudoccidental tropical, entre 1973 i 2018, es resumeixen a partir d'una recopilació d'informes en els quals es van utilitzar diversos mètodes de recompte d'ocells marins. Aquests mètodes van incloure transsectes lineals, observacions directes amb telescopi o prismàtics i recomptes exhaustius, segons l'espècie observada i el seu hàbitat de nidificació. Es donen estimacions de la grandària de les poblacions i dels períodes reproductius. El nombre total d'espècies d'ocells marins reproductors registrades a les dues illes va ser n = 14. Aquesta xifra total inclou les espècies d'ocells marins que crien a les dues illes (n = 7): petrell alanegre *Pterodroma nigripennis*, baldriga del Pacífic *Ardenna pacifica*, cua de jonc cua–roig *Phaethon rubricauda*, mascarell emmascarat *Sula dactylatra*, mascarell bru *Sula leucogaster*, nodi comú *Anous stolidus* i nodi argentat *Anous albivitta*. L'illa Hunter també alberga una petita colònia de petrell del Herald *Pterodroma heraldica* i colònies de fregata petita i fregata gran *Fregata ariel* i *Fregata minor* i de mascarell cama–roig *Sula sula*, com també de nodi negre *Anous minutus* i de xatrac blanc comú *Gygis alba*. A l'illa Matthew hi ha una gran colònia de xatrac fosc *Onychoprion fuscatus* i és possible que també s'hi reprodueixi un petrell de tempesta indeterminat. Les diferències en la composició de la comunitat d'ocells marins entre les dues illes s'expliquen per l'absència d'arbres a l'illa Matthew i la presència de la rata de la Polinèsia *Rattus exulans* a l'illa Hunter. Els nodis comuns es reprodueixen exclusivament durant l'estiu austral, igual que els petrells alinegres i les baldrigues del Pacífic, mentre que el petrell del Herald i les dues fregates semblen reproduir–se preferentment a l'hivern. El cua de jonc cua–roig, els tres mascarells, el nodi argentat i el xatrac fosc semblen reproduir–se durant tot l'any. Les pertorbacions causades per les activitats humanes han estat irregulars però devastadores per a les colònies d'ocells marins. La diversitat i l'abundància d'espècies d'ocells marins que es reprodueixen en aquestes illes les converteixen en llocs d'importància regional per a la conservació.

Paraules clau: Ocell marí, Població, Reproducció, Amenaces, Rata de la Polinèsia, Helicòpters

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Introduction

Rich seabird communities once thrived on the islands of the tropical Pacific. Many were locally driven to extinction as a result of habitat loss and predation by humans and introduced mammals (Steadman, 1993; Steadman et al., 1999, 2002; Duffy, 2010). Uninhabited islands are now the last sanctuaries for oceanic seabirds (Brooke, 2004; U.S. Fish and Wildlife Service, 2005; Duffy, 2010). Given the global decline of seabirds (Paleczny et al., 2015; IUCN, 2019), it is important to preserve such sites from further human intrusion. In this paper we address the significance of two remote volcanic islands in the southwestern tropical Pacific, Matthew (or Leka) and Hunter (or Fearn or Umaenupne) (Sharp, 1960; David, 1995; David, 2011), which potentially qualify as such sanctuaries for tropical seabirds. An updated, detailed description of the seabird communities breeding on these two islands of this still–poorly surveyed oceanic region is needed. Such an assessment is timely, as discussions are currently under way to possibly erect these islands as natural reserves within the newly created Natural Park of the Coral Sea (*Parc naturel de la mer de Corail*; Martin and Lecren, 2014; Fonfreyde et al., 2018).

The marine avifauna of Matthew and Hunter Islands has been briefly mentioned in a handful of papers in the scientific literature (Barritt, 1976; Rancurel, 1976; Condamin and de Naurois, 1987; Barré et al., 2007), supplemented by a number of mission reports in the grey literature from 1973 to 2018. Altogether, the foregoing reports concern over four decades of opportunistic observations. Although based on limited information, the two islands have been recognized as breeding bird areas of international importance (Spaggiari et al., 2007). Compiling the sparse knowledge available, the objectives of the present paper are (i) to describe the seabird communities of Matthew and Hunter islands, (ii) to estimate population sizes, (iii) to provide insights into their breeding cycles, and (iv) to assess the threats they potentially face.

Material and methods

Study sites

Matthew and Hunter Islands (fig. 1, 2) are the emerged summits of two volcanoes along the Hunter ridge, an oceanic volcanic chain oriented west to east, parallel to the Southern New Hebrides trench and 85 km north of it (Maillet et al., 1986). Oceanic waters of the surrounding Fiji basin are considered as moderately oligotrophic, with a net pimary productivity below ca. 200 $g.m^{-2}.yr^{-1}$ (Boyd et al., 2014). Two meteorological seasons can be distinguished in this tropical oceanic region of the southern hemisphere: a hot season that extends from October to March, with an average sea–surface temperature reaching between 27ºC and

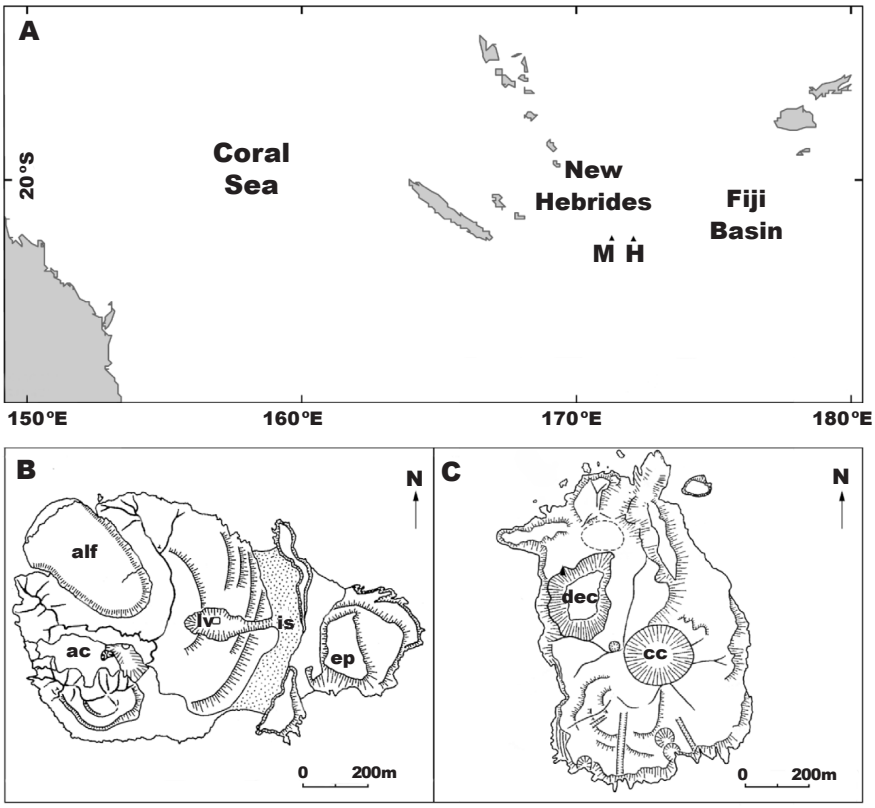

Fig. 1. A, map of the tropical southwestern Pacific region showing the positions of Matthew (M) and Hunter (H) Islands. B, map of Matthew Island (after Maillet et al., 1986): ac, active crater; alf, aa–lava flow; ep, eastern peak; is, isthmus; lv, lateral vent and radial gorge. C, map of Hunter Island (after Maillet et al., 1986): cc, central crater; dec, deep explosion crater.

Fig. 1. A, mapa de la región tropical del Pacífico suroccidental que muestra la localización de las islas Matthew (M) y Hunter (H). B, mapa de la isla Matthew (según Maillet et al., 1986): ac, cráter activo; alf, aa–flujo de lava; ep, pico oriental; is, istmo; lv, chimenea lateral y garganta radial. C, mapa de la isla Hunter (según Maillet et al., 1986): cc, cráter central; dec, cráter de explosión profunda.

28 ºC in February; and a fresher season, extending from April to September, with an average sea–surface temperature being as low as 23 ºC in August (Donguy and Henin, 1981).

The area of Matthew Island 1,200 m long and 750 m wide, is 68.3 ha (Butaud and Jacq, 2015). This island consists of a conical, active volcano 177 m above sea level on its western side ('West Matthew': Maillet et al., 1986) and a more eroded pyramidal basalt peak 142 m above sea level on the eastern side ('East Matthew'). The two are separated from one the other by a flat isthmus of black sand and lava scree, oriented north–south, and reaching a few meters above sea level in its middle part. With its large basaltic walls, vertical cliffs and active crater, Matthew Island offers the view of an essentially mineral landscape (fig. 2A). Hunter Island, whose area is 57.1 ha (Butaud and Jacq, 2015), consists of a massive, steeply–sloping

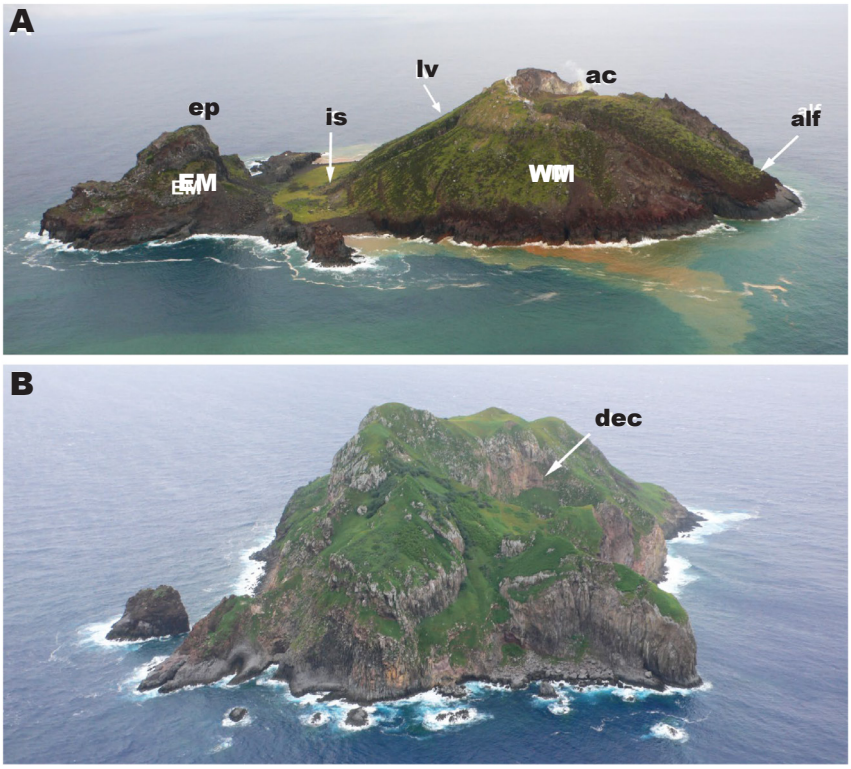

Fig. 2. Aerial view of the two study sites: A, Matthew Island (22º 20' S, 171º 19' E) seen from its North–West: ac, active crater; alf, aa–lava flow; EM, East Matthew; ep, eastern peak; is, isthmus; lv, lateral vent and radial gorge; WM, West Matthew (IRD/P. Borsa; 17/04/2008). B, Hunter Island (22º 24' S, 172º 03' E) seen from its North–West: dec, deep explosion crater (IRD/P. Borsa; 20/01/2009).

Fig. 2. Vista aérea de los dos lugares de estudio: A, isla Matthew (22º 20' S, 171º 19' E) vista desde su noroeste: ac, cráter activo; alf, aa–flujo de lava; EM, East Matthew; ep, pico oriental; is, istmo; lv, chimenea lateral y garganta radial; WM, West Matthew (IRD/P. Borsa; 17/04/2008). B, isla Hunter (22º 24' S, 172º 03' E) vista desde su noroeste: dec, cráter de explosión profunda (IRD/P. Borsa; 20/01/2009).

pyramidal structure 1,100 m long and 600 m wide, culminating at 242 m above sea level. The surface of the island is marked by several craters, faults, and a recent lava flow (fig. 2B). Both islands are fringed with inhospitable basalt cliffs but landing at the northern shore of Matthew Island's isthmus is possible by calm sea; Hunter Island is accessible via a boulder beach only by very calm sea (Rancurel, 1973; Condamin, 1978; Fonfreyde et al., 2018).

At the time of its discovery by European sailors, Matthew Island only consisted of the inhospitable basalt edifice that nowadays is East Matthew; West Matthew emerged in the late 1940s (Maillet et al., 1986). Rudimentary human–made constructions, a couple of stone artifacts and a small plantation of introduced *Erythrina variegata* shrub have been found on Hunter Island (Lardy et al., 1988b; Butaud and Jacq, 2015), indicating temporary occupa-

tion by, possibly, traditional fishermen in some recent past. Matthew and Hunter Islands are currently uninhabited. Nonetheless, throughout the period considered in this paper, these islands under French sovereignty and claimed by Vanuatu were visited at regular intervals by the New Caledonian armed forces (FANC) during surveillance and sovereignty operations (Pandolfi–Benoit, 1993; Girard and Borsa, 2008; Anonymous, 2009; Borsa and Baudat–Franceschi, 2019; Tenenbaum et al., 2020). In addition, the two islands are now visited nearly every other year by a team of the department of maritime affairs of the New Caledonian government (Fonfreyde et al., 2013, 2018; Anonymous, 2022). From 1983 until at least 1986, Matthew Island was occupied by rotating squads of the FANC, supplied and replaced by ships from the Noumea and, occasionally, Papeete navy bases (Pandolfi–Benoit, 1993).

Seabird breeding habitat

Butaud and Jacq (2015) have produced maps summarizing the characteristics of the vegetation of Matthew and Hunter Islands. A noticeable aspect of Matthew Island is the paucity of the vegetation, typical of a very young, remote island. A large portion of the sandy isthmus and the flanks of the main volcano have been colonized by an herbaceous heath comprising creeping vines *Ipomoea pes–caprae* and *Canavalia sericea*, and introduced grasses including introduced Mossman River grass *Cenchrus* sp. The southeastern flank of the main volcano and much of the northwesterly aa–lava flow (fig. 1B, 2A) are densely covered with a fern moor dominated by *Microsorum grossum*. However, more than half of the surface of Matthew Island consists of bare rock and sand. Hunter Island is more densely vegetated, with two main plant formations: a fern moor dominated by *Microsorum grossum* and herbaceous areas where Mossman River grass may locally abound. *Pisonia grandis* and *Pandanus tectorius* trees grow on the flanks of Hunter Island, on the flats and on the bottom of the two main craters. The cliffs are mostly without vegetation, as well as the surf zone all around the island.

Census of marine avifauna

We compiled census results from 23 ornithological visits to Matthew Island and Hunter Island between 1973 and 2018. That results of two visits were briefly reported in ornithology journals (Barritt, 1976; Barré et al., 2007) and 21 other visits led to informal reports (table 1), compiled pro parte in an informal report to the local authorities (Borsa and Baudat–Franceschi, 2019). Information relevant to estimating seabird population sizes and assessing breeding activity was extracted from these reports. Together, the co–authors of the present paper participated in five of the 13 visits to Matthew Island and in four of the ten visits to Hunter Island, recorded in table 1.

Because of the rugged terrain and the briefness of visits, only a portion of each island was surveyed each time. The portion varied. For instance, no census was made of the eastern half of East Matthew nor of the steep slopes at the periphery of Hunter Island because of their inaccessibility to pedestrians. Elsewhere, methods used to count seabirds have been reported in each of the reports listed in table 1, with references. These methods differed according to species, depending on nesting characteristics and nesting habitat. Sooty tern colonies (Matthew Island) were subsampled and nesting individuals, or chicks, were counted from a lookout using a telescope or binoculars (December 2004, June 2006). Lookouts were similarly used to count frigatebirds and red–footed boobies on Hunter Island (December 2004, June 2006). Nesting sooty terns were also counted using transects, as were nesting brown boobies, brown noddies, and grey noddies on Matthew Island (August 2004, December 2004). A convenient way to take a census of the grey noddies was to count them when they formed a large roosting group at sunset at the northern extremity of the isthmus of Matthew Island, as no other such large congregation was noted elsewhere on the island (August 2004). Masked boobies were counted exhaustively on the accessible parts of West

Table 1. Summary of visits dedicated to the observation of seabirds on Matthew and Hunter Islands and references to related notes and technical reports. PB, P. Borsa; JBF, J. Baudat–Franceschi; NA, information missing.

Tabla 1. Resumen de las visitas dedicadas a la observación de aves marinas en las islas Matthew y Hunter y referencias a notas e informes técnicos relacionados. PB, P. Borsa; JBF, J. Baudat–Franceschi; NA, falta información.

Date of visit	Ship, commander	Naturalist	Length of visit	Reference
Matthew Island				
3/11/1853	*Herald*, Denham	J. MacGillivray	NA	David (1995), W. R. P. Bourne (in litt.)
19/12/1973	*Bayonnais*e, de Maintenant	P. Rancurel	8 h 30 min	Rancurel (1973)
26/06/1974	*Hydra*, Read	M. K. Barritt	NA	Barritt (1976)
8/12/1977	*Dieppoise*, Célerier	M. Condamin	4 h 15 min	Condamin (1978)
6/08/1993	*Jacques Cartier*	M. Pandolfi–Benoit	A few h	Pandolfi–Benoit (1993)
29–30/09/1988	*Jacques Cartier*, Morillon	NA	NA	Lardy et al. (1988a)
11–12/08/2004	*Glorieuse*, Müller	PB	23 h	Borsa (2004)
13–14/12/2004	*Vendémiaire*, Lorge	PB	22 h	Borsa (2007), Borsa and Baudat–Franceschi (2019)
20/06/2006	*Vendémiaire*	JBF	5 h	Borsa and Baudat–Franceschi (2019)
17–18/04/2008	*Vendémiaire*, Arnoult	PB, JBF	33 h 10 min	Borsa and Baudat–Franceschi (2009a)
20–22/01/2009	*Vendémiaire*, Benon	PB, JBF	43 h	Borsa and Baudat–Franceschi (2009b)
17/05/2013	*Amborella*, Simoni	P. Bachy, JBF	10 h 30 min	Fonfreyde et al. (2013), Borsa and Baudat–Franceschi (2019)
2–3/06/2018	*Amborella*, Colombani	P. Bachy, J.–F. Butaud	2 d	Fonfreyde et al. (2018), Bachy (2020)
Hunter Island				
18/12/1973	*Bayonnaise*, de Maintenant	P. Rancurel	4 h 30 min	Rancurel (1973) de Maintenant
26/06/1974	*Hydra*, Read	M. K. Barritt	NA	Barritt (1976)
7/12/1977	*Dieppoise*, Célerier	M. Condamin	3 h 30 min	Condamin (1978)
15-29/09/1988	*Jacques Cartier*, Morillon	NA	NA	Lardy et al. (1988b)
12–13/12/2004	*Vendémiaire*, Lorge	PB	18 h	Borsa (2007)
11–12/10/2005	*Vendémiaire*	J. Spaggiari	1 d	Barré et al. (2007)
20–21/06/2006	*Vendémiaire*	JBF	1 d	Borsa and Baudat–Franceschi (2019)
20/01/2009	*Vendémiaire*, Benon	PB, JBF	2 h 20 min	Borsa and Baudat–Franceschi (2009b)
18/05/2013	*Amborella*, Simoni	P. Bachy, JBF	7 h 30 min	Fonfreyde et al. (2013), Borsa and Baudat–Franceschi (2019)
4–5/06/2018	*Amborella*, Colombani	P. Bachy, J.–F. Butaud	2 d	Fonfreyde et al. (2018)

Matthew (August 2004, December 2004, January 2009, May 2013). Subterranean–nesting petrels were detected by their nocturnal calls (Matthew Island: December 2004, January 2009; Hunter Island: December 2004); burrows detected by their entrances were explored by hand and the chick or adult was brought close to the entrance for identification (December 2004, April 2008, May 2013). No reliable count of burrows was possible, given that burrow entrances were generally hidden by tall tussock grass or ferns. However, it was possible to locate the colonies, as burrows were found exclusively in discrete patches of peat soil. During night time, a minimal number of breeding wedge–tailed shearwater individuals was counted from the number and direction of calls. During day time, a minimal number of breeding *Pterodroma* spp. petrels was estimated by counting nest entrances as indicated by the places where birds landed and disappeared into the vegetation.

Considering that: (1) at–colony abundance by species varies along the year; (2) the date of the visit to an island does not necessarily correspond to the peak of breeding; (3) breeding numbers fluctuate from one breeding season to another, depending on whether conditions are more or less favourable; and assuming that (4) the datasets used for the present work are free from methodological biases that might have led to overestimates, for each species we retained the highest estimate over all visits. The highest estimate was here assumed to be closest to the actual breeding population size. This estimate necessarily remains an underestimate of the size of the adult population of a given species, and therefore of the reproductive potential of the population when all the conditions are favourable.

Species richness and the Shannon diversity index [$-\Sigma_i p_i \ln(p_i)$, where p_i is the frequency of species *i* in the community (Shannon, 1948)], were calculated to describe the diversity of the seabird community of each island.

Breeding cycle

Two stages of the reproductive cycle were distinguished: egg, and chick or juvenile, i.e., adult–dependent young with flight feathers. The chronology of the various phases of the reproductive cycle was completed from the sparse data available by taking into account the duration of chick rearing. The latter, measured from hatching to departure, is ~ 80–130 days for *Pterodroma* spp. petrels (Brooke, 2004), 102–109 days for the wedge–tailed shearwater *Ardenna pacifica* (Pettit et al., 1984), 82.3 ± 0.6 days for the red–tailed tropicbird *Phaethon rubricauda* (Vanderwerf and Young, 2014), ≥ 97 days for the masked booby *Sula dactylatra* (Ainsworth and Webber, 2014), 100 days for the brown booby *S. leucogaster* (Yoda et al., 2004), 130 days for the red–footed booby *S. sula* (Nelson, 1969), 140 days for the lesser frigatebird *Fregata ariel* and 120 days for the great frigatebird *F. minor* (Diamond, 1975), 42.5 ± 4.03 days for the brown noddy *A. stolidus* in Hawaii (Brown, 1976), 39–47 days for the same species at Gough (Wilson et al., 2010) and 35 days for the grey noddy *A. albivitta* (Gochfeld et al., 2017).

Rodent trapping

Details on the number of rodent traps, types, density and trapping effort are provided in the relevant original reports (Borsa and Baudat–Franceschi, 2009a, 2009b, 2019; Fonfreyde et al., 2018). Briefly, Lucifer rat trap (Masy, Nouvion–le–Comte) lines were set during each of the April 2008, January 2009 and June 2018 visits to Matthew Island, and that of June 2018 to Hunter Island. The traps were baited with either peanut butter or coconut meat and left overnight for two nights (April 2008) or a single night (all other visits). On Matthew Island, twenty–four to 40 traps were placed over the vegetated part of the isthmus and on the lower eastern flank of the main volcano at a distance from one another of 25 m. On Hunter Island, 30 rat traps baited with coconut meat were set over the flats around the summit.

Impacts of visitors

We assessed the impacts of visits on the islands, and in particular, the impacts of helicopters, visually, in an opportunistic manner. All details were given in the original reports or in the original field notes and compiled in Borsa and Baudat–Franceschi (2019: table 16).

Results

Species present and nesting habitats

Eight seabird species were recorded breeding on Matthew Island (table 2): black–winged petrel *Pterodroma nigripennis* (fig. 3), wedge–tailed shearwater, red–tailed tropicbird, masked booby, brown booby, brown noddy, grey noddy, and sooty tern *Onychoprion fuscatus* (table 2). The possible occurrence of the white tern *Gygis alba* on Matthew Island (one pair observed in December 1977) has not been confirmed since then. Three individuals of an unidentified storm petrel were observed in the early morning of 18 April 2008 in rainy and windy weather conditions. These birds were making repeated passes above the two summits of Matthew Island, indicating possible nesting there. The burrows of black–winged petrels and wedge–tailed shearwaters were dug in peat patches located on the eastern flank of the main volcano, mostly at the bottom of the lateral vent. Red–tailed tropicbird nests occurred mostly in the cliffs of the lateral vent of the main volcano; nests were also found on the eastern flank of the main volcano and in the cliffs of the eastern peak. The nests of masked boobies were on a patch of turfgrass at the summit of the main volcano. Brown booby nests occupied the altitude beneath the turfgrass zone; nests were also found on the northern part of the isthmus. Brown noddy nests were scattered all over the lava boulder and rubble zones on either side of the isthmus. Sooty terns occupied the whole surface of the isthmus, the top of the northern and southern basalt scarps that delimitate the isthmus to its east, the lower half of the eastern flank of the main volcano, and the summit area of the large tongue–shaped aa–lava flow. Grey noddy nests were located under rocks and in the holes and cracks in the lava scree at the basis of the cliffs of the eastern peak and inside the radial gorge of the lateral vent of the main volcano.

Thirteen seabird species bred on Hunter Island, including all species that bred on Matthew Island except the sooty tern, as well as the Herald petrel *P. heraldica*, the lesser and great frigatebirds *Fregata ariel* and *F. minor*, the red–footed booby *S. sula*, the black noddy *A. minutus* and the white tern. The black–winged petrel, Herald petrel and wedge–tailed shearwater breeding colonies were located in the thick fern heath and grass prairies around the summits. Red–tailed tropicbird nests were located in the fern heath or in cracks, holes and burrows in the slopes beneath the summit. Lesser frigatebirds nested on the ground or on bushes inside the deep explosion crater and on the western flank of the summit of the island. Great frigatebirds nested in pisonia trees scattered all across the island. Masked boobies nested on the grass areas on the heights of the island, as well as flat areas at the bottom of cliffs in the periphery of the island. Red–footed boobies nested in the patches of pisonia tree at the bottom of the deep explosion crater, inside the central crater and on the eastern slope of the island. Brown noddies nested on the ground, with nests scattered all over the island. Grey noddy nests were scattered under rocks and in cracks in rocky slopes and lava scree. Black noddies and white terns nested in pandanus trees grouped in patches on the northern and southeastern slopes of the island. The white–tailed tropicbird *P. lepturus* was also observed flying over Hunter Island but no breeding was confirmed.

Table 2. Breeding seabirds recorded from Matthew and Hunter Islands, and population size estimates (in breeding pairs), based on reports from visits made between 1973 and 2018 (Rancurel, 1973; Barritt, 1976; Condamin, 1978; Lardy et al., 1988a, 1988b; Pandolfi–Benoit, 1993; Borsa, 2004, 2007; Borsa and Baudat–Franceschi, 2009a, 2009b, 2019; Fonfreyde et al., 2018). Maximum per species was taken as population size; + species present but no breeding ascertained; – species not recorded or mentioned; ? unidentified petrels present, but no breeding ascertained; *NA,* no visit to Hunter Island; ns, number of breeding pairs not specified; [a] minimal number of breeding pairs, from direct count (Borsa, 2007).

*Tabla 2. Aves marinas reproductoras registradas en las islas Matthew y Hunter y estimaciones del tamaño de la población (en parejas reproductoras), sobre la base de informes de visitas realizadas entre 1973 y 2018 (*Rancurel, 1973*;* Barritt, 1976*;* Condamin, 1978*;* Lardy et al., 1988a*,* 1988b*;* Pandolfi–Benoit, 1993*;* Borsa, 2004*,* 2007*;* Borsa and Baudat–Franceschi, 2009a*,* 2009b*,* 2019*;* Fonfreyde et al., 2018*). El máximo por especie se tomó como el tamaño de la población; + especies presentes pero sin cría comprobada; – especies no registradas o mencionadas; ? petreles no identificados presentes, pero sin cría comprobada;* NA*, ninguna visita a la isla Hunter; ns, número de parejas reproductoras no especificado; [a] número mínimo de parejas reproductoras mediante recuento directo (*Borsa, 2007*).*

	Date of visit											
Species	**Dec 1973**	**June 1974**	**Dec 1977**	**Sep 1988**	**Aug 1993**	**Aug 2004**	**Dec 2004**	**June 2006**	**Apr 2008**	**Jan 2009**	**May 2013**	**June 2018**
Matthew Island												
Pterodroma nigripennis	-	-	-	-	-	-	1[a]	-	+	~100	-	-
Ardenna pacifica	-	-	-	-	-	-	1[a]	-	+	> 2	≥ 2	-
Hydrobatidae sp.	-	-	-	-	-	-	-	-	+	-	-	-
Phaethon rubricauda	-	-	+	+	≤ 4	≥ 1	-	≥ 2	+	+	≥ 5	≥ 10
Sula dactylatra	-	-	-	-	1	8	23	3	+	18	31	~30
S. leucogaster	+	-	+	+	≥ 10	+	47[a]	3	2	23	+	-
Anous albivitta	+	-	+	+	≥ 100	~80	8[a]	≥ 70	14	7	+	≥ 200
A. stolidus	+	-	> 100	+	-	-	132[a]	-	+	> 37	+	< 10
Onychoprion fuscatus	≥ 10,000	+	> 1,000	> 1,000	≥ 1,000	-	6,210[a]	13,300	+	41	≤ 2,000	20,000
Gygis alba	-	-	1	-	-	-	-	-	-	-	-	-
Hunter Island												
Pterodroma heraldica	-	-	-	?	NA	NA	-	3	NA	-	+	20
P. nigripennis	-	-	-	?	NA	NA	4[a]	-	NA	≥ 5	-	-
Ardenna pacifica	-	-	-	?	NA	NA	15[a]	-	NA	-	-	-
Phaethon rubricauda	+	+	3	ns	NA	NA	29[a]	≥ 13	NA	≥ 9	+	32
S. dactylatra	-	-	-	ns	NA	NA	21	38	NA	-	96	~100
S. leucogaster	-	+	+	ns	NA	NA	18[a]	3	NA	-	+	10
S. sula	+	+	+	ns	NA	NA	324[a]	≥ 521	NA	≥ 2	+	> 100
Fregata ariel	-	+	+	ns	NA	NA	14[a]	≥ 414	NA	-	-	250 ± 50
F. minor	+	-	+	ns	NA	NA	4[a]	133	NA	+	+	60 ± 10
Anous albivitta	+	-	+	+	NA	NA	4[a]	21	NA	+	+	+
A. minutus	-	-	+	-	NA	NA	-	≥ 2	NA	-	-	+
A. stolidus	+	-	+	+	NA	NA	52[a]	-	NA	+	+	> 10
G. alba	-	-	+	1	NA	NA	9[a]	-	NA	~20	+	-

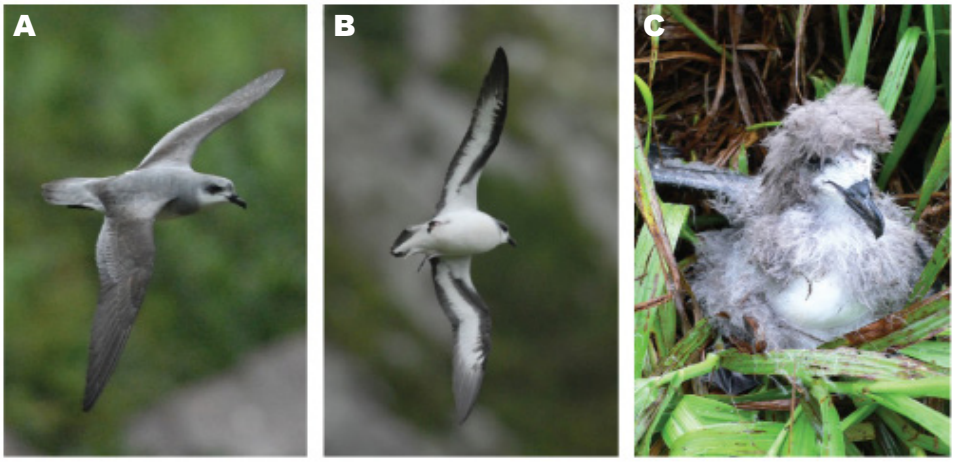

Fig. 3. Black–winged petrel *Pterodroma nigripennis* on Matthew and Hunter Islands (IRD/P. Borsa). Dorsal (A) and ventral (B) views of adult in flight, showing plumage patterns, January 2009. (C) Late stage of chick, with down remains and flight feathers underneath, April 2008.

*Fig. 3. Petrel alinegro (*Pterodroma nigripennis*) en las islas Matthew y Hunter (IRD/P. Borsa). Vistas dorsal (A) y ventral (B) de un adulto en vuelo, mostrando patrones de plumaje, enero de 2009. (C) Polluelo en fase avanzada de desarrollo con restos de plumón y plumas de vuelo en la parte inferior, abril de 2008.*

Demography

On Matthew Island, seabird population sizes reached up to one hundred pairs for the black–winged petrel, an unknown number of pairs for the wedge–tailed shearwater, less than a dozen pairs for the red–tailed tropicbird, ca. 30 pairs for the masked booby, 47 pairs for the brown booby, more than 130 pairs for the brown noddy, 200 pairs for the grey noddy and possibly up to 20,000 pairs for the sooty tern (table 2). The total number of seabirds was ≥ 21,875 breeding pairs, heavily dominated by the sooty tern. Species richness was ≥ 8 and the Shannon diversity index was 0.16.

On Hunter Island there were up to ca. 20 breeding pairs of *Herald* petrel, at least five pairs of the black–winged petrel, more than 15 pairs of the wedge–tailed shearwater, more than 30 pairs of the red–tailed tropicbird, ca. 100 pairs of the masked booby and at least 18 pairs of the brown booby, more than 500 pairs of the red–footed booby, up to ca. 400 pairs of the lesser frigatebird, more than 130 pairs of the great frigatebird, a few pairs of the black noddy, more than 50 pairs of the brown noddy, up to 20 pairs of the grey noddy and ca. 20 pairs of the white tern (table 2). The total number of seabirds was ≥ 1,350 breeding pairs. Species richness was 13 and the Shannon diversity index was 1.69.

Brown noddies were observed dying from toxic gases as they were roosting close to the main vent at the bottom of the active crater of Matthew Island (January 2009). Tens of mummified grey noddies were found on the isthmus of Matthew Island in August 2004; their breast had been eaten and over half of them had been decapitated. On Hunter Island, we found evidence of rodent predation on seabirds in the form of incisor indentations on the surface of brown booby eggs (December 2004).

Breeding

Brown noddies bred exclusively during the austral summer, as did wedge–tailed shearwaters and black–winged petrels, while the Herald petrel and the two frigatebirds seemed to prefer the winter. The red–tailed tropicbird, the masked booby, the brown booby, the red–footed booby, the grey noddy and the sooty tern may breed in any season (table 3). No major differences in breeding phenology were evident between the two islands except, perhaps, in the brown noddy and in the masked booby. For instance, for both species no nest was observed on Hunter Island in January 2009 while nests with eggs and chicks were observed on Matthew Island.

Differences were observed in the breeding stage of sooty terns on Matthew Island, where adults on the slopes and in the southern part of the isthmus were incubating eggs, while those occupying the northern part of the isthmus fed large chicks (June 2006). Similar patterns in breeding habitat occupancy were noted in December 2004. Our observations thus show desynchronized sub–colonies in the sooty tern on Matthew Island, those in advanced breeding stage occupying the part of the island most protected from trade winds (the northern half of the isthmus) while those having laid eggs most lately were relegated to more exposed parts of the island.

Threats

No rodent was captured or seen on Matthew Island. Although unnoticed on Hunter Island in December 1973 and December 1977, Polynesian rats *Rattus exulans* were captured on Hunter Island in December 2004 and June 2018; unidentified rats, likely the same species, were seen in September 1988, June 2006, and January 2009.

Helicopters used by the FANC had a noticeable impact on breeding seabirds. The observed nuisances on both Matthew and Hunter Islands included the stress caused to grey noddies by the approaching noisy large flying object, the disturbance and destruction caused by the thrust of the rotating pales above sooty tern and brown noddy nests on Matthew Island (December 2004, January 2009) and booby nests and wedge–tailed shearwater burrows on Hunter Island (December 2004), and the destructive effect of the weight of the helicopter landing on the peat mined by shearwater burrows on Hunter Island (December 2004). The military exercises we observed on Matthew Island in August 2004 included target shooting with automatic rifles and the firing of distress rockets. The combat station from which the military officers practiced target shooting was located in the middle part of the isthmus, directly at the bottom of the extinct lateral vent east to the active crater. The detonations of automatic weapons reverberated due to the vertical basalt walls of the isthmus and the western wall of the eastern peak. From the first shot, red–tailed tropicbirds, hundreds of grey noddies nesting in the lateral vent, and masked boobies nesting around the summit of the volcano were flushed away. Flares were also fired at night from the center of the isthmus towards its northern beach, causing the sudden flushing of hundreds of grey noddies roosting on the boulders.

The lights of the ship anchored near Matthew Island also caused the grounding of grey noddies on the deck and a masked booby knocked itself out by colliding with the ship's superstructures (August 2004). The lights of the bivouac installed in the middle part of the isthmus of Matthew Island in August 2004 caused the stranding of a grey noddy. Disturbance by visitors was observed: flushing of a group of hundreds of grey noddies by one person travelling along the edge of the northern beach of Matthew Island (August 2004); brown noddy nests with abandoned eggs and chicks near the automatic meteorological station on Matthew Island while being serviced by technicians (December 2004); abandon of their nests by incubating masked boobies, death of a neglected young masked booby chick, and temporary desertion of its young chick by a male great frigatebird on Hunter Island (December 2004); desertion of their nest by egg–incubating brown boobies on Hunter Island (December 2004); trampling of occupied petrel and shearwater burrows on Hunter Island (December 2004, January 2009).

Table 3. Reproduction of seabirds on Matthew (M) and Hunter (H) Islands, based on reports from visits made between 1973 and 2018 (Rancurel, 1973; Barritt, 1976; Condamin, 1978; Lardy et al., 1988a, 1988b; Pandolfi–Benoit, 1993; Borsa, 2004, 2007; Borsa and Baudat–Franceschi, 2009a, 2009b, 2019; Fonfreyde et al., 2018). Colonies were visited in January, April, May, June, August and December. Reproductive status in October available for only two species. No survey occurred in February, March, July, and November: NA, no data.

*Tabla 3. Reproducción de aves marinas en las islas Matthew (M) y Hunter (H) según los informes de las visitas realizadas entre 1973 y 2018 (*Rancurel, 1973*;* Barritt, 1976*;* Condamin, 1978*;* Lardy et al., 1988a*,* 1988b*;* Pandolfi–Benoit, 1993*;* Borsa, 2004*,* 2007*;* Borsa and Baudat–Franceschi, 2009a*,* 2009b*,* 2019*;* Fonfreyde et al., 2018*). Las colonias se visitaron en enero, abril, mayo, junio, agosto y diciembre. El estado reproductivo en octubre está disponible únicamente para dos especies. No se realizaron muestreos en febrero, marzo, julio y noviembre: NA, sin datos.*

			Month							
Species	**Site**	**Phase**	**Jan**	**Apr**	**May**	**June**	**Aug**	**Sep**	**Oct**	**Dec**
Pterodroma heraldica	H	Egg	-	-	-	+	-	NA	-	-
		Chick	-	-	-	-	-	NA	+	-
P. nigripennis	M, H	Egg	-	-	-	-	-	NA	NA	-
		Chick	-	+	-	-	-	NA	NA	-
Ardenna pacifica	M, H	Egg	+	-	-	-	-	NA	NA	-
		Chick	-	+	+	-	-	NA	NA	-
Phaethon rubricauda	M, H	Egg	-	-	+	+	-	+	NA	+
		Chick	+	-	+	+	-	+	NA	+
Sula dactylatra	M, H	Egg	-	-	+	+	+	+	NA	+
		Chick	+	-	-	+	+	+	NA	+
S. leucogaster	M, H	Egg	+	-	-	+	+	+	NA	+
		Chick	+	-	-	+	-	+	NA	+
S. sula	H	Egg	-	-	-	-	-	+	NA	-
		Chick	+	-	-	+	-	+	NA	+
Fregata ariel	H	Egg	-	-	-	+	-	+	NA	-
		Chick	-	-	-	-	-	+	NA	+
F. minor	H	Egg	-	-	-	+	-	+	NA	-
		Chick	-	-	-	+	-	+	NA	+
Anous albivitta	M, H	Egg	-	-	-	+	+	-	NA	+
		Chick	-	-	-	-	-	-	NA	-
A. minutus	H	Egg	-	-	-	-	-	-	-	-
		Chick	-	-	-	-	-	-	-	-
A. stolidus	M, H	Egg	+	-	-	-	-	-	NA	+
		Chick	+	-	-	+	-	-	NA	+
Onychoprion fuscatus	M	Egg	+	-	+	+	+	+	NA	-
		Chick	+	-	+	+	+	+	NA	+
Gygis alba	H	Egg	-	-	-	-	-	NA	NA	-
		Chick	-	-	-	-	-	NA	NA	-

Discussion

Species diversity

A better knowledge of the seabird colonies on these remote islands will be useful to managers, scientists and the civil society to engage in their conservation. Fourteen seabird species were recorded breeding on Matthew and Hunter Islands, including seven species common to both islands: black–winged petrel, wedge–tailed shearwater, red–tailed tropicbird, masked booby, brown booby, brown noddy and grey noddy. The lack of shrubs or trees on Matthew Island explains that the red–footed booby, the great frigatebird, the black noddy and the white tern do not breed there while breeding on neighbouring Hunter Island, as these species generally breed on shrubs or trees (Gauger, 2020; Gauger Metz and Schreiber, 2020; Niethammer and Patrick, 2020; Schreiber et al., 2020). The lesser frigatebird also bred exclusively on Hunter Island. In addition, the Herald petrel was recorded breeding on Hunter Island and not yet on Matthew Island. Conversely, the sooty tern, which is the most abundant seabird on Matthew Island, was not seen on Hunter Island. Besides Hunter Island, sooty terns are notably absent from rodent–infested sites of the Coral Sea including Walpole Island, Île Longue (Chesterfield atoll) and the coral islets of New Caledonia's northwestern lagoon (Spaggiari et al., 2007; Baudat–Franceschi et al., 2009; Borsa et al., 2010). They are present in very low numbers on Surprise Islet (d'Entrecasteaux atolls, Coral Sea), another rodent–infested islet until 2005 (Robinet et al., 1997; Caut et al., 2008), and on islets in the northern and southern lagoons of New Caledonia where the Polynesian rat thrived until recently (Pandolfi–Benoit and Bretagnolle, 2002; Baudat–Franceschi et al., 2009; Baudat–Franceschi, 2012). The presence of the Polynesian rat on Hunter Island (Borsa, 2007) may thus explain the absence of sooty terns there, but the more–limited area of open space favourable to the nesting of the sooty tern on Hunter Island relative to neighbouring Matthew Island might be an alternative explanation. All seabirds that breed in Matthew or Hunter Island have been previously recorded as breeders from the New Hebrides archipelago or adjacent regions of the tropical southwestern Pacific (Harrison, 1985; Brooke et al., 2004; BirdLife International, 2018a).

Other gadfly petrel species occurring in the region include the collared petrel *Pterodroma brevipes* which breeds in Vanuatu and Fiji (Bretagnolle and Shirihai, 2010; del Hoyo et al., 2020), the white–necked petrel *P. cervicalis* which breeds in Vanuatu, Norfolk Island and the Kermadec archipelago (Brooke, 2004), Gould's petrel *P. leucoptera* which has sizable colonies on New Caledonia's Grande Terre (Bretagnolle et al., 2021) and may also breed in Vanuatu (Brooke, 2004), the Vanuatu petrel *P. occulta* recorded breeding on volcanic islands in the Banks islands (Shirihai and Bretagnolle, 2010; Kirwan et al., 2020), and the Tahiti petrel *Pseudobulweria rostrata* which has a wide distribution, including breeding colonies in New Caledonia, Vanuatu and Fiji (de Naurois, 1978; Carboneras et al., 2020). Although the foregoing species are apparently absent from Matthew and Hunter Islands, we emphasize that the effort allocated to surveying seabird colonies there so far has been limited. Future ornithological surveys might yield additional species to the three petrel species recorded to date on Matthew and Hunter Islands.

Several of the larid species breeding on islets elsewhere in the Coral Sea, including the silver gull *Chroicocephalus novaehollandiae*, the bridled tern *O. anaethetus*, the roseate tern *Sterna dougallii*, the black–naped tern *S. sumatrana*, the crested tern *Thalasseus bergii* and the fairy tern *Sternula nereis* (Rancurel, 1976; Borsa and Vidal, 2018) do not breed on Matthew and Hunter Islands. These are all coastal species, which in this region of the world forage in the shore, reef, and lagoon habitats. These types of habitat are absent from Matthew and Hunter Islands or around.

Abundances

For most species, population size estimates fluctuated considerably from one visit to another. Seasonality of breeding may explain part of this variability. Other factors should be considered, such as the possible, occasional presence of predators, e.g. the peregrine falcon *Falco peregrinus* as this species is a predator of terns and possibly other seabirds in the tropical southwestern Pacific (Bregulla, 1992; Baudat–Franceschi, 2012).

For each species, the proportion of the gobal population represented by the colonies of Matthew and Hunter Islands was tentativey estimated (table 4). Although the figures reported in table 4, both from our survey and from the literature, are probably incomplete, they highlight the grey noddy as an outlier. The breeding population size of the grey noddy on Matthew Island (an outstanding > 4 % of the estimated global population; BirdLife International, 2018a) makes it a site of conservation significance for this species. Aside from Matthew and Hunter Islands, the grey noddy occurs on a limited number of islands in the southwestern Pacific, including Kermadec, Lord Howe, Norfolk and Tonga (Gill and Donsker, 2019). The breeding population size of the the red–tailed tropicbird and of the lesser and great frigatebirds on Hunter Island might reach several 0.1 % (that is, a substantial proportion) of the global total. The fact that the latter three species all show decreasing trends elsewhere (BirdLife International, 2018b, 2020b, 2020d) further emphasizes the conservation significance of this site.

Several of the species that occur on Matthew and Hunter Islands once bred on islets in the southern lagoon of New Caledonia: these include the masked booby and the brown booby (de Naurois and Rancurel, 1978). The red–footed booby still breeds in this lagoon but only as a small colony on its southernmost islet, the most remote from human settlements (Pandolfi–Benoit and Bretagnolle, 2002; Baudat–Franceschi, 2012). The extirpation or near–extirpation of these species from the southern lagoon has been ascribed to disturbance by human visitors (Pandolfi–Benoit and Bretagnolle, 2002). The Herald petrel was once recorded from the Chesterfield Islands but it may have been extirpated from these islands, presumably because of guano–digging (Bourne et al., 2005). Another species, the red–tailed tropicbird, once bred in the Chesterfield islands, where it has not been studied since 1973 (Borsa, 2021). Until the late 19th century this species was also abundant at the d'Entrecasteaux atolls but fewer than a dozen breeding pairs have been reported recently (Borsa et al., 2021). It is likely that the remoteness and inhospitality of Matthew and Hunter Islands have so far helped protecting these sensitive species from human disturbance (but see next sub–section).

Threats

Identified threats to seabirds on Matthew and Hunter Islands included disturbance due to human activities, trampling of burrows, military drills, helicopter movements, and lights on shore and on board ships moored near the island. In addition, Hunter Island is infested by the Polynesian rat. It is likely that the presence of Polynesian rats on Hunter Island limits the reproduction of noddies, white terns and gadfly petrels,and may have caused or accelerated the extinction of storm petrels, such as the white–throated storm petrel, whose range extends over a wide oceanic region that includes Matthew and Hunter Islands (Brooke, 2004; BirdLife International, 2018b). Larger seabirds, like the brown booby, are not immune from predation by the Polynesian rat on Hunter Island.

Although only occasional, human visits to Matthew and Hunter Islands have a disastrous impact. The impact of helicopters is particularly strong. The simple visual impact of a large flying object approaching causes stress among nesting seabirds; the noise of turbines and rotating blades is a proven threat (Brown, 1990). The configuration of Matthew's isthmus is a special case; the basaltic scarps reverberate the sounds and concentrate them towards the lateral vent, which is the nesting area of several species, including the black–winged petrel, the wedge–tailed shearwater, the red–tailed tropicbird, and the grey noddy. The disturbance

Table 4. Global population size of 14 seabird species from Matthew and Hunter Islands and proportion represented locally.

Tabla 4. Tamaño global de la población de 14 especies de aves marinas de las islas Matthew y Hunter y proporción representada localmente.

Species	Global population size	Reference	Global number of breeding adults (pairs)	Matthew+Hunter Islands % global population
Pterodroma heraldica	150,000 ind.	Brooke (2004)	< 75, 000	<< 1 %
P. nigripennis	8–10 million ind.	Brooke (2004)	< 4-< 5 million	<< 1 %
Ardenna pacifica	> 5,200,000 ind.	Brooke (2004)	< 2,600,000	<< 1 %
Phaethon rubricauda	70,000 mature ind.	BirdLife International (2020d)	5,000	< 1 %
Sula dactylatra	'rather common'	Stotz et al. (1996)	na	na
S. leucogaster	200,000 ind.	BirdLife International (2018d)	< 100,000	< 1 %
S. sula	1,400,000 mature ind.	Birdlife International (2021)	700,000	< 1 %
Fregata ariel	100,000–500,000 ind.	BirdLife International (2018b)	< 50,000-< 250,000	< 1 %
F. minor	120,000 mature ind.	Kushlan et al. (2002)	60,000	< 1 %
Anous albivitta	10,000 mature ind.	BirdLife International (2018a)	5,000	4.4 %
A. minutus	1,300,000 mature ind.	Partners in Flight (2019)	650,000	<<1 %
A. stolidus	800,000–1,400,000 mature ind.	BirdLife International (2020a)	400,000-700,000	< 1 %
Onychoprion fuscatus	23 million mature ind.	BirdLife International (2020c)	11,500,000	< 1 %
Gygis alba	25,000–49,999 mature ind.	Wetlands International (2022)	< 12,500-< 25,000	<< 1 %

caused by helicopter operations led to the likely permanent abandonment of many masked booby, brown booby, sooty tern and brown noddy nests situated around the landing zones. The thrust of the rotating blades is powerful enough to not only sweep tern eggs and chicks away, but also to molest and hurt booby chicks and adults and to damage shearwater burrows. Red–footed booby and frigatebird nests built in trees are also vulnerable.

Another dramatic impact of human visits has been mentioned by Lardy et al. (1988b) who reported a bushfire 'accidentally' set on Hunter Island in March 1983. The fire raged for one month, burning most of the vegetation of the island, including the dense *Pisonia* forest which then covered its slopes and summits, and destroyed an estimated 80 % of the booby and frigatebird nests.

Conservation recommendations

Predation by alien mammals has exerted a heavy toll on many petrel species, to the point that a large proportion of them are now endangered (Croxall et al., 2012). Matthew Island appears to be free of rodents although this needs to be confirmed. Given that Matthew Island was occupied for years by army squads regularly provisioned by landing ships departed from military docks in Nouméa and Papeete, it is possible that mice and rats have been introduced on Matthew Island, perhaps repeatedly, at a time when biosecurity was not as much considered an issue as it is today. However, these animals may have been unable to survive prolonged periods of drought such as those linked to El Niño events (Terry and Raj, 2002). Strict measures should be taken to limit the risk of introduction or reintroduction of rodents on this island. An urgent conservation need of the avifauna on Hunter Island is the eradication of the Polynesian rat, a well–known predator of seabirds (Jones et al., 2008). This is especially important to protect smaller subterranean or ground–nesting seabirds such as the black–winged petrel and the Herald petrel. Such eradication might allow the eventual recolonization of Hunter Island by the sooty tern and possibly storm petrels.

It remains to be verified that the storm petrels observed at sea between Hunter Island and Matthew Island by Barritt (1976) and and on Matthew Island by ourselves (Borsa and Baudat–Franceschi, 2009a; Baudat–Franceschi, 2010) were white–throated storm petrels *Nesofregetta fuliginosa*. If it were so, regardless of the size of the population, the presence on Matthew Island of this endangered species now reduced to an estimated few hundred pairs globally (BirdLife International, 2018c) would make it a site of extreme importance for its conservation. Another possible storm petrel candidate could be the New Caledonian storm petrel *Fregetta lineata*, recently discovered breeding in New Caledonia (Bretagnolle et al., 2022). In this case again, stakes would be considerably high, as *F. lineata* is already considered an 'almost certainly globally threatened' species (Bretagnolle et al., 2022).

Another, urgent measure to be taken is to limit disturbance to seabirds. Given the damage observed on seabird colonies by helicopter operations and the risk of collision with seabirds (Borsa, 2007), we recommend banning helicopter flights over Matthew and Hunter Islands. We also recommend banning rifle–shooting exercises. Finally, human visits to these islands should be restricted to a minimum, regarding both the number of people, the duration of their visits and the extent of their activities.

Conclusion

The present compilation of observations acquired during short, opportunistic visits to Matthew and Hunter Islands within the last five decades provides a unique insight into the breeding avifauna on these two remote and inhospitable islands of the tropical southwestern Pacific. An island free of alien predators, as Matthew Island seems to be, makes it a rare sanctuary for petrels and other seabirds in that region of the world. The results of the present study advocate for the full protection of Matthew and Hunter Islands. A high priority should be given to the eradication of the Polynesian rat on Hunter Island.

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