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A review of the seabirds of Phillip Island in the Norfolk Island Group

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Abstract Few places have been as ecologically devastated by the introduction of exotic mammals as Phillip Island in the Norfolk Island Group. Pigs (*Sus scrofa*), goats (*Capra hircus*) and rabbits (*Oryctolagus cuniculus*) denuded the island so severely that massive amounts of soil and underlying substrate were lost through erosion. Rabbits, the last of these exotic animals to be removed, were eradicated during the 1980's. Since then the extent of vegetation on the island has been increasing by natural revegetation and through plantings and seeding. Fourteen species of seabird currently breed on Phillip Island. Five species—Providence petrel (*Pterodroma solandri*), Kermadec petrel (*P. neglecta*), white-naped petrel (*P. cervicalis*), flesh-footed shearwater (*Puffinus carneipes*) and red-tailed tropicbird (*Phaethon rubricauda*)—all have ecologically significant populations. In this paper, we review the current status of the seabird populations breeding on Phillip Island, and suggest how vegetation restoration is likely to affect each species. We update previously published notes and present unpublished material collected by us over more than 3 decades. We document when each species was first discovered, reveal the location of nesting sites, describe breeding phenology and nesting habitat, report on any banding activities and returns, and discuss potential threats.

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INTRODUCTION

The Norfolk I Group (29°02'S, 167°57'E) comprises Norfolk I (3455 ha), Phillip I (190 ha), Nepean I (10 ha) and a number of smaller islets. It is situated in the south-west Pacific Ocean approximately 1670 km north-east of Sydney, Australia and approximately 1070 km north-west of Auckland, New Zealand. Polynesians visited the islands from about 1000 AD (Specht 1978; Meredith *et al.* 1985), but when Commander James Cook discovered the islands in 1774 they were uninhabited. The British claimed sovereignty and, in 1788, established a small settlement on Norfolk I, which later expanded to become a penal colony housing more than 1100 people (Hoare 1999; Coyne 2010). The penal colony was abandoned in 1814, but was re-established in 1825. The second settlement, of up to 3000 people, was abandoned in 1855. The following year, the entire population of Pitcairn I (194 descendants

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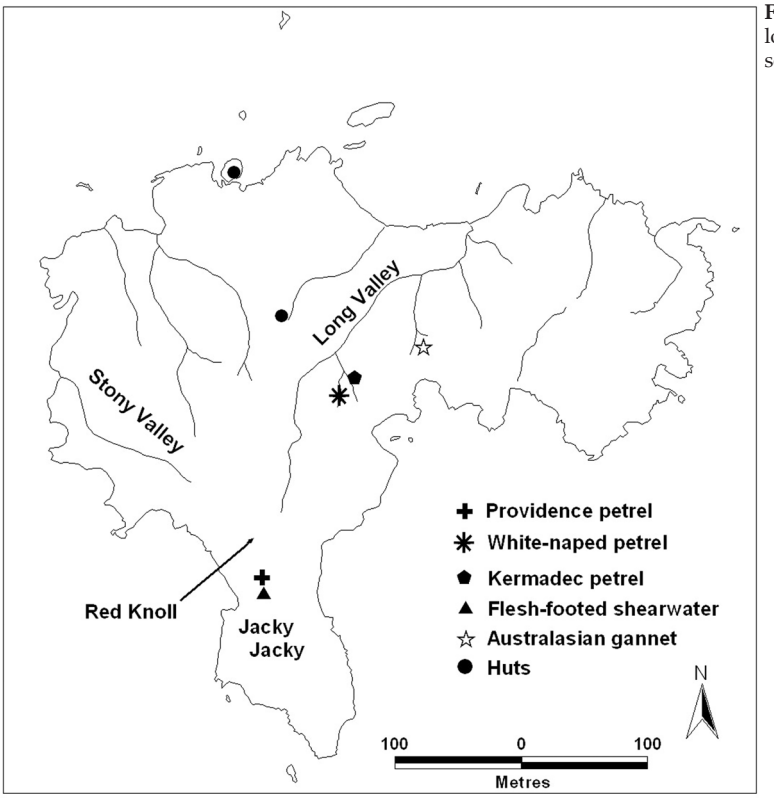

Fig. 1. Phillip I showing the approximate locations of nesting sites of those seabirds with small local populations.

of the mutineers from HMS *Bounty* and Tahitian women) moved to Norfolk I to establish a free colony (Hoare 1999).

Phillip I (29°07′S, 167°57′E) lies approximately 6 km south of Norfolk I. It rises to a summit of 280 m above sea level along the narrow Jacky Jacky Ridge on its southern peninsula (Fig. 1). The island consists of roughly equal amounts of basalt lava and tuff that erupted from the submerged Norfolk Ridge about 2.8 million years ago (Jones & McDougall 1973). When Europeans first set foot ashore they reported finding light red soil, of great depth, which was completely honey-combed with bird burrows (Edgecombe 1999; Medway 2002a). The original vegetation was never fully described, but in 1788 Lieutenant Philip King recorded the presence of about 150 "pine trees" and described most of the hills as being covered with a "thick entangled reed" (King 1789). Coyne (2010) combined the scant information from Phillip I with the better-documented records from Norfolk I to describe the likely condition of Phillip I prior to its degradation by exotic mammals. Based on this analysis, it is now thought that the island was heavily vegetated with species that included Norfolk I pine (*Araucaria heterophylla*) and white oak (*Lagunaria patersonia*), as well as a number of rainforest hardwoods and, probably, tree ferns (Coyne 2010).

Pigs (*Sus scrofa*) were liberated onto Phillip I to supply meat for the colony soon after the first Europeans settled on Norfolk I (Melville 1969). Despite the harvesting that must have occurred, the population rapidly increased to more than 300 animals (Collins 1798 in Coyne 2010). When the settlement on Norfolk I was abandoned in 1814, the pigs were left unchecked. The second settlement that began 11 years later harvested the pigs on Phillip I, but also introduced goats (*Capra hircus*) and rabbits (*Oryctolagus cuniculus*) (Fullagar 1978; Coyne 2010). The Pacific rat (*Rattus exulans*) and black rat (*R. rattus*) are present on Norfolk I (DEWHA 2009), but have not been recorded on Phillip I.

When the first detailed observations of the vegetation on Phillip I were recorded in 1830, the ridges were already denuded (Heward 1842) and the vegetation in the valleys altered to one dominated by the less palatable caper-bush (*Capparis nobilis*) (Melville 1969). The pigs died out, either naturally or through hunting, by about 1856. The goats were gone by about 1900, but by then, the island was already heavily degraded (Coyne 2010). The continued presence of rabbits, together with the sparseness of the vegetation and the friable nature of the volcanic soils, resulted in severe erosion. After heavy rain, red or brown plumes of suspended

sediments formed in the sea around Phillip I (Turner *et al.* 1968; Coyne 1981). Not only was the topsoil lost but, along with it, metres of underlying subsoil. A coarse assessment of the rate of erosion in 1979–80 recorded a mean annual loss of 42 mm (range 20–62 mm, $n = 8$) of substrate (Coyne 2010).

During the 1970's, concern grew about the devastation wreaked on the island and the continuing high rate of erosion. By 1978, at least 13 indigenous plant species, including 2 endemic species, had been lost from Phillip I (Fullagar 1978). In 1979, a number of fenced exclusion plots were constructed to examine the impact that rabbits were exerting on the environment. The prolific growth of vegetation within these plots after just 1 year demonstrated unequivocally how rabbits were preventing regeneration (Coyne 2010). These results convinced the Norfolk I Legislative Assembly to eradicate the rabbits from Phillip I (Coyne & Greenwood 1982). A protracted eradication campaign involving myxomatosis, poisoning, shooting, gassing and trapping then followed (Coyne 2010). Although the last rabbit was not removed until 1988, by 1984 most of the island was clear of rabbits, with survivors restricted to just 4 isolated beaches or cliff tops (DEH 2003; Coyne 2010). In 1996, Phillip I was incorporated into the Norfolk I National Park (Parks Australia 2000) and responsibility for its management was transferred to the Australian Government.

The removal of rabbits from Phillip I has led to much of the island becoming revegetated (Coyne 2010). The process of natural revegetation has been further aided by direct plantings and by broadcasting native seed (Green 1994). In 2002, approximately 73% of the island was vegetated (Cogger *et al.* 2006); 22% wooded and 51% with a ground cover of herbaceous plants, including both native and exotic species. Several plant species that were either unknown or presumed extinct on the island have since been found or rediscovered (Green 1994; de Lange & Murray 2001). Initially, weed removal focused on eradicating kikuyu grass (*Pennisetum clandestinum*) and controlling morning glory (*Ipomea* spp.), but this activity has since been expanded into a comprehensive weed control programme to remove all exotic species from within the major catchments (DEH 2003).

It is against this backdrop of accelerating change in the vegetation of Phillip I that we review the status of the seabirds currently breeding there. Two systematic surveys of the avifauna of the Norfolk I Group have been undertaken—the first in 1978 (Schodde *et al.* 1983) and the second in 2005 (Christian 2005), although the latter has yet to be published. Numerous other accounts of the birds of Norfolk I Group have been published (e.g., Hull 1910; Wakelin 1968; de Ravin 1975; McKean *et al.* 1976; Tarburton 1981; Moore 1981, 1985; Hermes 1985; Hermes *et al.* 1986; Moore 1999). Although several of these publications contain some information on the seabirds of Phillip I, they neither individually nor collectively provide a comprehensive account of current knowledge.

In this paper we collate all existing knowledge regarding seabird breeding activity on Phillip I up to 2007. In particular, we report when each species was first observed on the island and the location of nesting sites. We describe breeding phenology and nesting habitat, and detail new information about the breeding ecology of the species. We report on the number of birds banded and any significant band returns. We provide an estimate of the number of pairs of each species nesting on Phillip I, and assess the regional and global significance of these populations. We speculate how the ongoing programme to revegetate Phillip I is likely to affect each species. Finally, we identify and discuss potential threats.

METHODS

This paper, written by DP and NC, is based largely on observations and data collected by OE, BE and HM over several decades. Observations began in 1978 when regular visits to Phillip I commenced. Initially, trips involved daytime visits to band each annual cohort of masked boobies (*Sula dactylatra*). HM continues to make regular visits to the island to undertake this activity. Longer overnight trips to Phillip I by OE and BE commenced in Dec 1986 and continued at irregular intervals (depending largely on the species targeted) until May 1999. Specific efforts were made to locate and monitor the nests of the rare species. Diurnal and nocturnal observations were made, including the first arrival of birds on the island each year, the commencement of laying and hatching, and the time of fledging. All birds handled were banded.

Population sizes of most summer-breeding seabirds were estimated by DP and NC during a 2-day visit to Phillip I in Nov 2006. Nesting seabirds on Phillip I are patchily distributed, with burrow-nesting species restricted to areas of deep stable soil and tree-nesting species confined to wooded areas. All areas of potential nesting habitat, other than inaccessible cliffs, were identified from aerial photographs and systematically visited and searched for nesting seabirds. Binoculars were used to scan areas that were inaccessible. Rapid estimates were made of the number of nests or burrows based on density and area of extent. Population estimates are given as orders of magnitude, following Fullagar *et al.* (1974). Identification of burrowing species was either by: (i) observation of breeding individuals, (ii) identification of calls from within

burrows, or (iii) based on burrow-entrance size. Burrow occupancy rates vary markedly among species and populations (Waugh *et al.* 2003 and references therein), but typically are around 50%. Consequently, we assumed that only one half of all burrows were occupied. Population estimates of species not present on Phillip I in Nov 2006 were based on previous observations by OE, BE, HM and others. More precise estimates of breeding numbers require comprehensive surveys to be undertaken at multiple times of the year.

In addition to the sources described above, information was drawn from a range of historical records and published accounts, as well as some unpublished material. All such sources are acknowledged in the text. Avian nomenclature and taxonomy follow Gill *et al*. (2010).

RESULTS

Fourteen species of seabird currently breed on Phillip I: Providence petrel (*Pterodroma solandri*); Kermadec petrel (*P. neglecta*); white-naped petrel (*P. cervicalis*); black-winged petrel (*P. nigripennis*); wedge-tailed shearwater (*Puffinus pacificus*); flesh-footed shearwater (*P. carneipes*); little shearwater (*P. assimilis*); red-tailed tropicbird (*Phaethon rubricauda*); Australasian gannet (*Morus serrator*); masked booby; sooty tern (*Onychoprion fuscatus)*; brown noddy (*Anous stolidus*); black noddy (*A. minutus*); and blue-grey noddy (*Procelsterna cerulea*). Although the white tern (*Gygis alba*) breeds in profusion on Norfolk I, it currently does not occur on Phillip I. On Norfolk I it nests extensively in Norfolk Island pines, placing its egg directly onto a horizontal branch or limb, where it can be vulnerable to strong winds. White terns probably bred on Phillip I before the island was denuded, and may return when sheltered stands of pines have re-established.

Three additional species once bred within the Norfolk I Group but are now locally extinct. A storm petrel (presumably the Kermadec storm petrel, *Pelagodroma albiclunis*), a prion (*Pachyptila* sp.) and Pycroft's petrel (*Pterodroma pycrofti*) are all present in the fossil record (Meredith 1991; Holdaway & Anderson 2001). Pycroft's petrel was also present in the faunal remains left by Polynesians (Meredith 1991). A painting considered to be of this species suggests that it was still present in 1800 (Holdaway & Anderson 2001) as do the bones found in the refuge dumps of the early European settlement (Meredith 1991). All 3 extinct species are small and highly vulnerable to rats and it is possible that the Pacific rat, brought by the Polynesians, played a role in their demise on Norfolk I (Holdaway & Anderson 2001).

Two other species—Newell's shearwater (*Puffinus newelli*) and a frigatebird (*Fregata* sp.)—have been seen ashore on Phillip I, but do not currently breed there or elsewhere within the Norfolk I Group. A single Newell's shearwater was caught at night on 2 Dec 1997 (Moore 1999), at the end of the fledging period (early Nov to mid Dec) of the nearest colony, 6640 km away on Kauai in the Hawaiian Is (Telfer *et al.* 1987). A group of 8 frigatebirds was seen roosting on Phillip I in 2004 (Christian 2005).

Additional bird species observed on Phillip I since 1986 include: swamp harrier (*Circus approximans*), nankeen kestrel (*Falco cenchroides*), Pacific swamphen or pukeko (*Porphyrio melanotus*), rock pigeon (*Columba livia*), Norfolk Island boobook (*Ninox novaeseelandiae*; call heard), Norfolk Island kingfisher (*Todiramphus sanctus*), Eurasian blackbird (*Turdus merula*), welcome swallow (*Hirundo neoxena*), silvereye (*Zosterops lateralis*), house sparrow (*Passer domesticus*), European greenfinch (*Carduelis chloris*) and European goldfinch (*C. carduelis*).

Providence petrel

Providence petrels have been found in archaeological deposits on Norfolk I dating from Polynesian settlement (Holdaway & Anderson 2001) and were present when the island was first settled by Europeans in 1788 (Whitley 1934; Hindwood 1940; Medway 2002a). In Mar 1790, HMS *Sirius* carrying convicts, marines and much-needed provisions was wrecked on a reef while unloading at Norfolk I. Although most of the livestock and provisions were salvaged, it left the island with many extra mouths to feed (the population increased from 149 to 507, Medway 2002a) and insufficient food. During the next 4 months the island's garrison, convicts and marooned sailors avoided starvation by slaughtering hundreds of thousands of Providence petrels. In the 4 breeding seasons between 1790 and 1793, about 1 million Providence petrels, adults and young, were harvested (Medway 2002a). Continued harvesting, together with the depredations of introduced pigs, which by 1796 numbered 15,000 (Schodde *et al.* 1983), saw the entire population of petrels extirpated from Norfolk I by about 1800.

It appears that the Providence petrel also bred on Phillip I, and there are unsubstantiated reports that it may have survived there until at least 1900 (Hull 1910; Christian 2005). Providence petrels were rediscovered on Phillip I on 3 Jul 1985 (Hermes *et al.* 1986) and breeding was confirmed 12 days later when an egg was found.

We estimate the current population of Providence petrel on Phillip I to be 10–100 breeding pairs. In 1986, the population was estimated to be at least 20 birds (Hermes *et al.* 1986). The highest single count of adults was 38 flying birds, in May 1992. The Providence petrel is classified globally

as vulnerable (BirdLife International 2009d). It is not know whether the population on Phillip I is genetically distinct from that on Lord Howe I, the only other breeding locality for this species where the breeding population is estimated to be approximately 32,000 pairs (Bester 2003). Banding started in 1991, and to date a total of 77 Providence petrels (including 20 nestlings) have been banded, with no recoveries away from Phillip I.

The Providence petrel is a winter breeder, and birds on Phillip I breed about the same time as those on Lord Howe I. Adults arrive at Phillip I from mid Apr and chicks have been noted in near-fledged condition in early Nov. Adults land during daylight, often about 1530 h. There is a single record of a Providence petrel seen on the island in late Dec, outside the known breeding season.

All known burrows are in eroded cliffs of soft volcanic tuff along a narrow, sparsely vegetated, precipitous ridge between Red Knoll and the summit (Fig. 1). Wedge-tailed and little shearwaters have also excavated burrows in these softer sediments. Most Providence petrel burrows are >1 m long; some exceed 5 m. The length of these burrows, together with the horizontal entrances in near-vertical banks, lead us to believe that they are relics that date back to the time before pigs and goats were let loose on the island. Although the soil around the entrances has eroded, 2 centuries ago these burrows were probably too inaccessible and too deep to be excavated by pigs. It seems plausible that subsequent generations of petrels have continued to use and lengthen these burrows, and that, contrary to previously held beliefs (e.g., Schodde *et al.* 1983; Medway 2002a), the Providence petrel was never completely extirpated from the Norfolk I Group. If, as believed, the population of Providence petrel on Phillip I is the last remaining vestige of the much larger population that once occurred within the Norfolk I Group, it is historically significant.

The population of Providence petrel on Lord Howe I breeds within forest (Bester 2003), as once did the population on Norfolk I (Medway 2002a), suggesting that the current breeding habitat on Phillip I is atypical and that further revegetation of Phillip I is likely to benefit this species. A more serious threat to the survival of the small population of Providence petrel on Phillip I is competition for burrows from wedge-tailed shearwaters, an interaction that has been observed since 1991. From mid Oct each year, returning and prospecting pairs of wedge-tailed shearwaters kill or eject some Providence petrel chicks from their burrows. Up to 4 wedge-tailed shearwaters have been observed collectively attacking and expelling a petrel from its burrow. The fate of the expelled chicks is unknown.

Kermadec petrel

Kermadec petrels were first recorded on Phillip I on 5 Aug 1986, when 3 adults were found ashore (Moore 1999). Breeding was confirmed on 31 Dec 1987 when a nesting pair was found (Woods 1988). Four adults plus a fully grown nestling were located on 20 Feb 1992 (Moore 1999). There is no definitive evidence that Kermadec petrels had bred on Phillip or Norfolk Is at any time earlier. However, as these islands lie within the breeding distribution of the Kermadec petrel it is reasonable to suspect that they formally bred there (Holdaway & Anderson 2001). Kermadec petrels are surface nesters, and so are highly vulnerable to introduced predators (Schlatter 1984; Taylor 2000b). Previous populations, if they existed, are likely to have been quickly extirpated by pigs or rats.

The history of Kermadec petrel on Norfolk I is uncertain. Meredith (1991) unearthed fossil leg bones on the island that were intermediate in size between Providence petrel and Pycroft's petrel and assigned these to an undescribed species. Holdaway and Anderson (2001) suggest that these bones may be of the Kermadec petrel, signifying a long association with Norfolk I.

We estimate the current population of Kermadec petrels on Phillip I to be 10–100 breeding pairs. The Kermadec petrel breeds throughout the South Pacific, as far east as the Juan Fernandez and Desventuradas Is off the coast of Chile, and has a global breeding population of about 50,000 pairs (Brooke 2004). Although the Kermadec petrel is currently classified as least concern (BirdLife International 2009c), there have been some significant historical declines. The population on Raoul I in the Kermadec Is Group, estimated at 500,000 birds in 1908 (Iredale 1914), is now virtually extinct because of predation from rats and cats (Merton 1970). The species is also extinct from Lord Howe I, but a small population (10–100 pairs) still breeds on Balls Pyramid, 23 km to the south-east (Fullagar *et al*. 1974).

Banding commenced in Nov 1988, and a total of 12 Kermadec petrels (including 3 nestlings) have been banded on Phillip I. Recaptures show that individuals generally use the same nest site each year. A bird that hatched in Dec 1990 returned to the colony in Nov 1993, when approaching 3 years of age, but did not breed. No bands have been recovered away from Phillip I.

The Kermadec petrel on Phillip I is a summer breeder. Birds have been found ashore from early Aug (Moore 1999), with eggs laid as early as 12 Oct, and hatching as early as 30 Nov. A single egg measured 67 x 45 mm. Incubation shifts of 2 days (n = 3), 4 days (n = 1), 7 days (n = 1) and 10 days (n = 1) have been recorded. Chicks are brooded for 3 days before both parents simultaneously begin

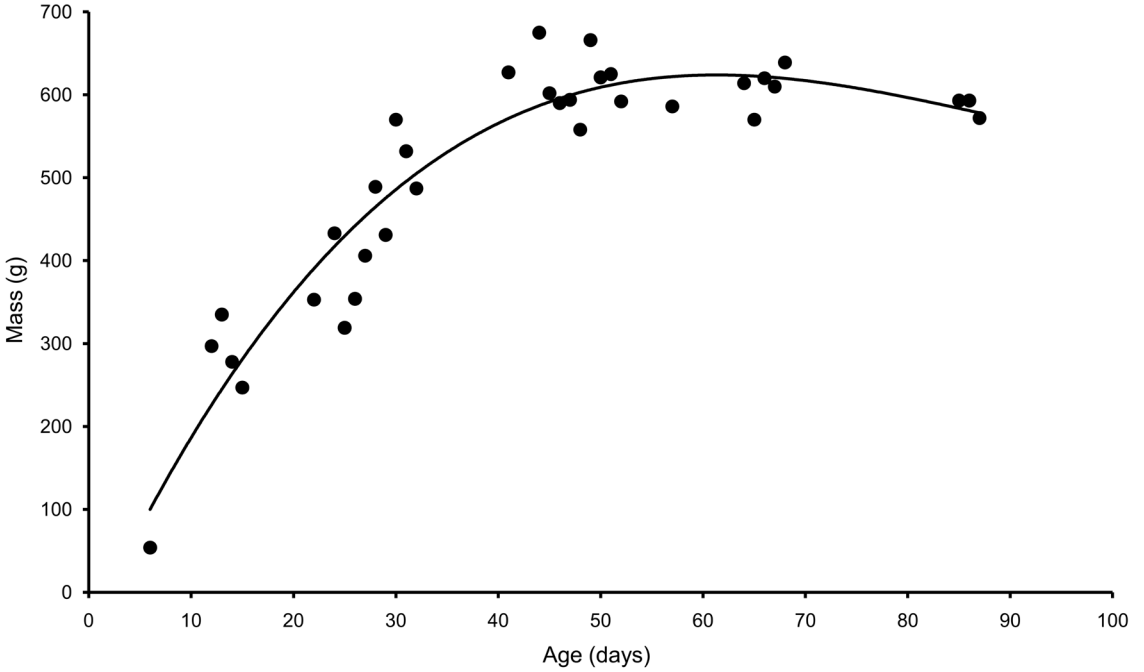

Fig. 2. Mass of a single Kermadec petrel chick 6–87 days after hatching. This individual fledged when 97 days old.

provisioning trips. During 1993, the weight of a single chick was monitored throughout much of the nestling period (Fig. 2).

On Phillip I, Kermadec petrels breed in the upper reaches of Long Valley (Fig. 1). They nest on the ground, currently under a dense, low canopy of windswept African olives (*Olea africana*), but previously have nested within clumps of New Zealand flax (*Phormium tenax*). Nesting petrels and their young rely on vegetative cover for protection from the elements and from avian predators. On Phillip I, raptors have been observed to take adult Kermadec petrels. Although African olive is an invasive weed and is a species targeted for control (Parks Australia 2000), removal of the particular stands of olives used by Kermadec petrels should be postponed until the species has nested successfully under native vegetation.

Kermadec petrels returning to provision their chicks are sometimes harassed and forced back out to sea by black-winged petrels. It is not known whether the breeding success of Kermadec petrel is being compromised by this interaction. The pukeko is suspected of destroying the eggs of Kermadec petrel nesting within stands of New Zealand flax, and is probably the reason why the petrels no longer breed in this particular habitat. The population of Kermadec petrel on Phillip I is so small that any predation of eggs or chicks poses a serious threat to the population.

White-naped petrel

White-naped petrels had not been recorded within the Norfolk I Group until 21 Apr 1991 when 2 birds were found ashore on Phillip I, in the upper reaches of Long Valley (Fig. 1). Breeding was confirmed in Feb 1992 when 4 birds were found, including 1 brooding a chick.

We estimate the population of white-naped petrels on Phillip I to be 10–100 breeding pairs. The number of known nests increased from 6 in 1994 to 20 in 2005. Seventeen white-naped petrels (including 7 nestlings) have been banded on Phillip I, with no recoveries away from the island. The white-naped petrel is classified globally as vulnerable (BirdLife International 2009b). The majority of the world's population breeds on Macauley I, where there were estimated to be 50,000 pairs in 1988 (Tennyson *et al.* 1989). Up to 500 pairs once nested on Raoul I (Iredale 1910), but the species no longer breeds there; the population was probably destroyed by feral cats and rats (Tennyson *et al.* 1989; Taylor 2000a). Recently, there have been unconfirmed reports of white-naped petrels breeding on Mere Lava in Vanuatu where the species is apparently well known to locals (MacAllan in BirdLife International 2009b).

Very little is known about the breeding biology of the white-naped petrel (Marchant & Higgins 1990). On Phillip I, it is a summer breeder. Birds come ashore as early as 11 Nov, but eggs have not

been detected until 8–31 Jan (data from 6 years combined). A single fresh egg measured 67.5 x 47.0 mm and weighed 84 g. Eggs hatched from 22 Feb and fledglings departed 19–30 May when 87–94 days old (n = 3) and weighing 425 g (n = 1).

On Macauley I, white-naped petrels nest exclusively in burrows (Taylor 2000a). On Phillip I, however, they nest among boulders and in crevices in rocky habitat with sparse understorey below a canopy of mature white oaks that provides concealment from avian predators. They have also nested in artificial cavities. The only known nesting locality for this species on Phillip I is at the top of Long Valley, but other areas that contain an abundance of rock cavities under a dense canopy offer potential nesting sites.

Black-winged petrel

Black-winged petrels were not recorded within the Norfolk I Group until 1965 when a specimen was collected for the National Museum in Melbourne (Schodde *et al.* 1983). This species was first confirmed breeding on Phillip I in 1968 (Schodde *et al.* 1983). In recent decades, the black-winged petrel has expanded its distribution across the southwest Pacific (Klapste 1981; Jenkins & Cheshire 1982; Powlesland 1985; Tennyson 1991; Hutton & Priddel 2002). The establishment and growth of the population on Phillip I is consistent with this expansion. Repeated attempts by black-winged petrels to establish on Norfolk I have largely been thwarted by cats (Schodde *et al.* 1983; Christian 2005). Only where cat numbers have been reduced have black-winged petrels been successful (Christian 2005).

We estimate the population of black-winged petrels on Phillip I to be 1000–10,000 pairs, significantly greater than earlier estimates of 50–100 pairs (Tarburton 1981) and "several hundred birds" (Hermes *et al.* 1986). In all, 116 black-winged petrels (including 2 nestlings) have been banded on Phillip I, with no recoveries away from the island.

The black-winged petrel is a summer-breeding migrant, present locally between Oct and late May. The earliest recorded arrival on Phillip I is 31 Oct. Eggs are laid in late Dec or Jan. Chicks generally hatch in Feb and fledge in May. The timing of breeding on Phillip I is similar to that on Lord Howe I (Hutton & Priddel 2002).

In 1978, nesting on Phillip I was restricted to cliff faces where the birds nested in burrows and under rocks (Schodde *et al.* 1983). In 2006, black-winged petrels also nested in extensive colonies in soil burrows on the lower slopes of most vegetated valleys. On other islands black-winged petrels typically nest in burrows or in rock cavities under grass, tussocks or shrubs (Jenkins & Cheshire 1982; Merton 1984; Hutton & Priddel 2002). Thus, the continued revegetation of Phillip I is unlikely to diminish the nesting opportunities for this species.

Wedge-tailed shearwater

The wedge-tailed shearwater is present in Polynesian archaeological deposits on Norfolk I (Holdaway & Anderson 2001) and was recorded during the first years of European occupation (Schodde *et al.* 1983). This ubiquitous species was first recorded on Phillip I in 1908 (Hull 1910), nesting in shallow soil burrows on the northern slopes of the island. In 1978, the species was nesting on the upper slopes at both the northern and southern parts of the island (Schodde *et al.* 1983). Breeding birds still occupy these areas.

We estimate the current population of wedge-tailed shearwater on Phillip I to be 1000–10,000 pairs. In 1981, the population of wedge-tailed shearwaters on Norfolk I was estimated to be "several hundred thousand" with the species being "less common" on Phillip I (Tarburton 1981). Fifty-nine wedge-tailed shearwaters (including 6 nestlings) have been banded on Phillip I, with no recoveries away from the island.

Breeding is highly synchronous. Birds arrive on Phillip I in the third week of Oct (16–21 Oct, n = 10 years: 1977–1986), and laying commences about 13 Dec. Most fledglings usually depart 6–18 May.

Wedge-tailed shearwaters are abundant in the tropical and subtropical oceans of the world. They breed throughout the Pacific and Indian oceans. Locally, they breed on islands along the eastern seaboard of Australia as far south as Montague I, and on the Kermadec Is (Marchant & Higgins 1990). On Phillip I, smothering of nesting sites by the introduced kikuyu grass is a potential threat to this species. Current practice to control this highly invasive weed (Parks Australia 2000) should continue.

Flesh-footed shearwater

The flesh-footed shearwater appears in the catalogue of the British Natural History Museum as having been collected on Norfolk I in 1896 (Saunders & Salvin 1896 in Holdaway & Anderson 2001), but whether it was taken at sea or on one of the islands is not known. Holdaway and Anderson (2001) raised the possibility that flesh-footed shearwater material exists unrecognized in the fossil collections of Norfolk I. However, this species is not listed in any of the early accounts of the island's avifauna.

Numerous individuals of this species were seen at sea between Norfolk and Phillip Is in Nov 1975 (during the breeding season for this species) (McKean *et al.* 1976) and a single bird was found ashore on Norfolk I among wedge-tailed shearwaters on 16 Nov 1979 (Moore 1985).

Local fishers regard the flesh-footed shearwater as a common visitor (McKean *et al.* 1976), although Schodde *et al*. (1983) listed the species as a vagrant, erroneously in our opinion.

Flesh-footed shearwaters were first observed on Phillip I in Oct 1993 when 2 were captured, on different days, in the same burrow (Moore 1999) near the summit. Between 1993 and 1996, birds were seen regularly in this location, from mid Nov. On 14 Nov 2006, a pair of flesh-footed shearwaters was observed on the summit, entering a burrow together. The flesh-footed shearwater is a summer breeder. The earliest that a bird has been recorded ashore is 10 Oct. Although breeding has not been confirmed, the presence of birds in burrows and the regularity of their occurrence strongly suggest that the species breeds on the summit of Phillip I.

We estimate the population of flesh-footed shearwater on Phillip I to be 1–10 pairs. This small population is only the second breeding colony of this species in eastern Australia, the other being on Lord Howe I (Fullagar *et al.* 1974). However, the species also breeds on several islands off the southern coast of Australia (100,000–200,000 pairs, Ross *et al.* 1996), on numerous islands in New Zealand (25,000–50,000 pairs, Taylor 2000b), and Ile St Paul in the Indian Ocean (600 pairs, Marchant & Higgins 1990). The flesh-footed shearwater is classified globally as least concern (BirdLife International 2009e). Only 4 flesh-footed shearwaters (all adults) have been banded on Phillip I, with no recoveries away from the island.

The revegetation of Phillip I is unlikely to disadvantage the flesh-footed shearwater, which typically nest in forests. It is likely that the breeding success of this species is affected by competition from the other species—Providence petrel and wedge-tailed shearwater—that use the burrows on the summit of Phillip I. The potential interactions among these species warrant further investigation.

Little shearwater

Little shearwaters occur in Polynesian deposits on Norfolk I (Holdaway & Anderson 2001). The first modern definitive record of little shearwaters within the Norfolk I Group dates from Gould's (1838) description of the species (Schodde *et al.* 1983). The first report of this species on Phillip I was in 1908 (Hull 1910), although this may have been based on local information rather than a first-hand account.

We estimate that the population of little shearwaters on Phillip I to be 100–1000 pairs, as did Schodde *et al*. (1983). Although the species has a circumpolar distribution, the subspecies *assimilis* breeds only within the Lord Howe and Norfolk groups. It is uncommon on Lord Howe I and it has been lost from Norfolk I, surviving only on islets where introduced predators are absent. Consequently, the little shearwater is regarded as vulnerable within Australia (Garnett & Crowley 2000).

The little shearwater is a winter breeder, with adults arriving on Phillip I as early as 19 Apr. Eggs are laid from 7 Jul and hatch from 2 Sep (Hermes *et al.* 1986). We have found fledglings still present up until 29 Nov, and Schodde *et al*. (1983) reported finding them in early Dec. Fledglings are sometimes evicted from burrows that, in summer, are used by wedge-tailed shearwaters. Potentially, little shearwaters may also compete for burrows with black-winged petrels, as happens on Lord Howe I (Priddel *et al.* 2003). A total of 171 little shearwaters (including 11 nestlings) have been banded on Phillip I, with no recoveries away from the island.

On Phillip I, little shearwaters nest in shallow burrows on coastal and inland slopes, some of which are vegetated with shrubs or trees, while others are devoid of cover. On Lord Howe I this species breeds under dense canopy up to 25 m from open ground (Priddel *et al.* 2003) and thus revegetation on Phillip I is unlikely to adversely affect it.

On misty evenings during Nov, the population on Nepean I (and possibly Phillip I) suffer losses of fledglings when they are attracted to unshielded lights at Kingston on the southern shore of Norfolk I. Once grounded the birds are vulnerable to predation by dogs and cats. Concerned residents attempt to minimise any losses by searching the area during such weather conditions and capturing, for later release, any grounded birds.

Red-tailed tropicbird

The red-tailed tropicbird has been present in the Norfolk I Group at least since European settlement (Iredale 1955; Hindwood 1965; Schodde *et al.* 1983). The nest, a simple scrape on the ground, is usually sited on sea cliffs, under a bush or rocky overhang (Tarburton 1979; Schodde *et al.* 1983). On Norfolk I, nests also occur at the base of Norfolk I pines which can be up to 40 m from a cliff face (Tarburton 1979). On Phillip I some nests occur under low-growing white oaks.

We estimate there to be 100–1000 pairs of red-tailed tropicbird on Phillip I, one of the largest breeding colonies of this species in Australia. A previous estimate of 30–100 pairs in the late 1970's (Schodde *et al.* 1983) is regarded as an underestimate (Hermes *et al.* 1986). The red-tailed tropicbird has a wide tropical and subtropical distribution, and breeds on numerous islands in the Pacific and Indian oceans (Marchant & Higgins 1990). In all, 109 red-tailed tropicbirds (including 7 nestlings) have been banded on Phillip I. There has been a single recovery away from Phillip I: a bird banded in Jan 1991 was recovered at sea in Feb 2001 after

colliding with a boat approximately 360 km west of Phillip I.

The red-tailed tropicbird breeds during the summer, although some birds are present year round. Breeding birds begin returning to Phillip I in Oct. Most eggs are laid between Dec and Feb, however, eggs have been laid as early as 11 Nov and as late as 11 Mar. Incubation shifts of up to 13 days have been recorded. Chicks are present from early Jan to late Jul, but most depart in Jun. Due to the cliff-nesting habit of this species, the revegetation of Phillip I is unlikely to affect it.

Australasian gannet

The first record of Australasian gannets within the Norfolk I Group dates from Nov 1961 when a pair was found nesting on Nepean I (McKean *et al.* 1976). They were first observed on Phillip I in 1968, within the upper catchment of Long Valley (Fig. 1). They were not confirmed to be breeding there until 1974 when 2 pairs were found incubating (McKean *et al.* 1976). Since then, up to 4 pairs have bred at the same site (McKean *et al.* 1976; Moore 1999). Two pairs were breeding there in Nov 2006.

The small population of Australasian gannets on Phillip I is the most northerly breeding colony of this species (Marchant & Higgins 1990). Despite producing at least 27 fledglings since 1990, the population has not increased, possibly because birds breeding at these low latitudes are at their physiological or ecological limits (Schodde *et al.* 1983).

In all, 31 Australasian gannets (including 27 nestlings) have been banded on Phillip I. A nestling from the 1994–95 cohort was recaptured in 1996 on Belops I, New Caledonia (Moore 1999); 1100 km NNW of Phillip I. There have been no other recoveries away from the Norfolk I Group. The founding birds of the Phillip I colony may well have originated from New Zealand, where the number of Australasian gannets increased between 1946 and 1980 (Wodzicki *et al.* 1984). The nearest colony to Phillip I is on the Three Kings Is, approximately 700 km to the south-east, where some 10,000 pairs nest (Wodzicki *et al.* 1984).

The Australasian gannet is a summer-breeding species. Eggs are laid between late Aug and early Feb and hatch mid Nov to mid Mar; chicks fledge from 22 Jan (Hermes *et al.* 1986). Birds have been seen mating with masked boobies, but no hybrid young have been detected (Garnett & Crowley 2000). Regenerating native vegetation on those areas on Phillip I currently used by gannets may eventually prevent this species from nesting there.

Masked booby

The masked booby features prominently in the Polynesian deposits on Norfolk I (Holdaway & Anderson 2001), and was one of the few seabirds described by Commander James Cook when he discovered the islands in 1774 (Hoare 1999). The species was first recorded breeding on Phillip I in 1908 (Hull 1910), where the initial vegetation changes may have increased the extent of suitable nesting habit.

Before the 1981–82 breeding season, a total of 88 masked boobies (66 nestlings, 22 adults) had been banded on Phillip I. Subsequently, a concerted effort has been made to band a substantial proportion of each annual cohort of young (the frequency of visits depending on sea conditions). As a result, between Nov 1981 and Dec 2007, 3163 nestlings were banded, an annual mean (± SD) of 117 ± 65 (range = 24–294, n = 27 years). Based on these data, the population of masked boobies on Phillip I exceeded 300 breeding pairs. A previous estimate, in 1978–79, put the population at 100 pairs (Tarburton 1981).

In all, 39 individuals banded on Phillip I have been recovered at locations up to 1779 km away (Table 1). Recoveries have been from: Nepean I (n = 3); Norfolk I (n = 4); New Caledonia (n = 4); Middleton Reef, New South Wales (n = 1); Vanuatu (n = 17); Hamilton, New Zealand (n = 1); Kermadec Is (n = 5); Fraser I, Queensland (n = 1); and Swains Reef, Queensland (n = 3).

The breeding season on Phillip I is protracted. Eggs are laid early Jul – early Jan, but the peak laying period is around Sep. Hatching generally occurs early Sep – late Mar (although hatchings as late as 9 May have been recorded). Most chicks fledge Jan – Mar (Hermes *et al.* 1986) although chicks are present almost year-round. The peak in breeding on Phillip I is about 3–4 weeks later than that on Nepean I.

Masked boobies typically nest in open habitats. Currently, on Phillip I they are thinly dispersed across much of the island. As the extent of vegetation increases it is likely that masked boobies will become more restricted to windswept headlands and other areas that cannot support trees or shrubs.

Sooty tern

The sooty tern has been present within the Norfolk I Group since at least the time of European settlement (Hindwood 1965), and was first documented breeding on Phillip I in 1908 (Hull 1910). Nowadays it breeds in loose colonies wherever the soil has been stabilised by low open vegetation that provides shelter and concealment for eggs and chicks.

The eggs of the sooty tern are harvested by islanders, a practice that dates back to a period of intermittent supply of imports to this remote settlement. The harvest is legally sanctioned and regulated, with the annual collecting season ending

Table 1. Recoveries of banded masked boobies away from Phillip I.

Band number	Date banded	Age banded	Elapsed days	Recovery location	Longitude	Latitude	Status	Distance (km)
13148590	20 Nov 1982	Nestling	735	Nepean I	167.950°E	-29.067°S	Alive	6
13149212	20 Nov 1982	Nestling	1120	Nepean I	167.950°E	-29.067°S	Alive	6
13150703	24 Nov 1984	Adult	385	Nepean I	167.950°E	-29.067°S	Alive	6
13149221	20 Nov 1982	Nestling	1180	Norfolk I	167.950°E	-29.033°S	Alive	10
13217999	05 Dec 2003	Nestling	340	Ball Bay, Norfolk I	167.983°E	-29.033°S	Dead	10
13146757	21 Nov 1981	Nestling	2837	N Anson Bay, Norfolk I	167.917°E	-29.017°S	Dead	12
13167643	02 Dec 1991	Juvenile	4652	20 km NE Norfolk I	167.750°E	-28.883°S	Dead	32
13146761	05 Dec 1981	Nestling	238	20 km SSE Noumea	166.633°E	-22.383°S	Dead	760
13150656	14 Nov 1984	Adult	5821	Noumea Harbour	166.506°E	-22.462°S	Dead	770
13184343	03 Dec 1993	Nestling	185	Pourina	165.750°E	-21.833°S	Dead	839
13146853	19 Feb 1982	Nestling	>2904	Middleton Reef, NSW	159.167°E	-29.417°S	Dead	854
13217989	05 Dec 2003	Nestling	774	Ouvea, New Caledonia	166.450°E	-20.550°S	Dead	964
13189610	05 Nov 1996	Juvenile	132	Anelngauhat, Vanuatu	169.733°E	-20.233°S	Alive	1004
13146739	21 Nov 1981	Nestling	194	Tanna I, Vanuatu	169.283°E	-19.550°S	Dead	1072
13157591	21 Feb 1988	Adult	181	Tanna I, Vanuatu	169.333°E	-19.500°S	Alive	1074
13184505	01 Mar 1995	Nestling	141	Tanna I, Vanuatu	169.300°E	-19.500°S	Alive	1078
13184592	23 Dec 1994	Nestling	452	Tanna I, Vanuatu	169.333°E	-19.500°S	Alive	1078
13146739	21 Nov 1981	Nestling	224	1 km off Tanna I	169.283°E	-19.550°S	Alive	1078
13148616	12 Feb 1983	Nestling	149	10 km NE Hamilton	175.300°E	-37.767°S	Dead	1178
13146768	05 Dec 1981	Nestling	159	29 km from Efate I	168.300°E	-17.750°S	Alive	1264
13172665	30 Jan 1992	Nestling	167	Pele I, Vanuatu:	168.417°E	-17.467°S	Dead	1296
13050913	17 Jan 1981	Nestling	3193	Curtis I, Kermadec Is	178.550°W	-30.533°S	Alive	1300
13151235	30 Jan 1987	Juvenile	672	Macauley I, Kermadec Is	177.450°W	-30.217°S	Alive	1309
13157548	13 Feb 1988	Nestling	293	Macauley I, Kermadec Is	177.450°W	-30.217°S	Alive	1309
13157606	21 Feb 1988	Adult	285	Macauley I, Kermadec Is	177.450°W	-30.217°S	Alive	1309
13157611	02 Dec 1987	Nestling	366	Macauley I, Kermadec Is	177.450°W	-30.217°S	Alive	1309
13172685	29 Feb 1992	Juvenile	308	Uleveo I, Vanuatu	167.817°E	-16.533°S	Alive	1399
13150726	11 Jan 1986	Nestling	185	At sea, Tisvel, Vanuatu	167.500°E	-16.250°S	Dead	1426
13167678	28 Jan 1992	Nestling	218	Ambryn I, Vanuatu	168.167°E	-16.250°S	Alive	1431
13184456	04 Nov 1994	Nestling	394	NW Malekula, Vanuatu	167.000°E	-16.000°S	Dead	1461
13150709	19 Dec 1985	Nestling	>378	Malo I, Vanuatu	167.183°E	-15.667°S	Alive	1492
13146755	05 Dec 1981	Nestling	443	West Malo, Vanuatu	167.167°E	-15.667°S	Dead	1497
13167728	27 Dec 1989	Nestling	244	Ambae, Vanuatu	167.750°E	-15.417°S	Dead	1523
13212150	03 Dec 2000	Nestling	292	Fraser I, Queensland	153.121°E	-24.717°S	Dead	1548
13172707	20 Feb 1992	Juvenile	271	Mota Lava, Vanuatu	167.667°E	-13.667°S	Dead	1718
13157618	02 Dec 1987	Nestling	236	Swain Reefs	152.483°E	-21.983°S	Alive	1740
13172855	23 Dec 1992	Nestling	2393	Swain Reefs	152.483°E	-21.983°S	Alive	1740
13167401	07 Feb 1989	Juvenile	888	Swain Reefs	152.417°E	-21.742°S	Alive	1760
13172762	07 Dec 1992	Nestling	176	Hiu I, Vanuatu	166.583°E	-13.167°S	Dead	1779

on 30 Nov (*Birds Protection Act* 1913). Historically, Nepean I was a favoured collecting site, with the result that the population there collapsed. In 1908, between 10,000 and 15,000 eggs were harvested from this island several times a week (Hull 1910). In 1978, only 'several hundred' birds bred there (Schodde *et al.* 1983).

We estimate the current population of sooty terns on Phillip I to be 1000–10,000 pairs. Some previous estimates (10,000 pairs in 1977, Fullagar in Schodde *et al.* 1983; and 40,000–70,000 pairs in 1978 and 1979, Tarburton 1981) are higher, suggesting that the population has declined. However, a more precise estimate of 8000 nestlings on Phillip I in Jan 1985 (Hermes *et al.* 1986) is less suggestive of a catastrophic decline in the population.

The sooty tern is a summer breeder, but laying dates and breeding success can vary markedly between years (O'Neill 2006). On Phillip I, birds are heard flying overhead as early as Aug, but typically do not begin laying until the second week of Oct (Hermes *et al.* 1986). If the egg is lost or fails, sooty terns are capable of relaying, but only after a period of approximately 6 weeks has elapsed (O'Neill 2006). Sooty tern eggs on Phillip I are harvested, so laying (and relaying) continues up until the end of Jan. Chicks are present from early Nov to the end of Mar, but most do not appear until Jan. Fledglings are present late Jan to Apr with the last birds not departing until late May (Hermes *et al.* 1986). Like elsewhere, breeding success on Phillip I (the number of eggs that produce flying young) varies widely between years (4–55% between 1986–87 and 1988–89, ANPWS in Moore 1999).

Sooty terns lay their eggs in a scrape or depression in open habitats. Further revegetation of Phillip I is likely to concentrate this species onto headlands and other areas of low vegetation. The resulting increase in nesting density is unlikely to reduce the breeding productivity of this species, which often nests in dense colonies. Nesting densities on Phillip I are currently low, and increasing this may enhance the colony's ability to defend itself from avian predators. In recent years, many sooty tern eggs, particularly those in New Zealand flax, have been destroyed by pukeko.

Brown noddy

It is likely that the brown noddy nested on Norfolk and Phillip Is before European arrival, but, like the other tern species, no remains have been preserved in the archaeological record (Holdaway & Anderson 2001). Although the description is not entirely clear, it seems that this species was first recorded within the Norfolk I Group during the 1838–39 breeding season (Iredale 1955).

No brown noddies were seen on Phillip I in early Nov 2006, but previous estimates are within the range 100–1000 pairs (Tarburton 1981; Fullagar in Schodde *et al.* 1983; Hermes *et al.* 1986). No brown noddies have been banded on Phillip I.

The brown noddy is a summer breeder that is typically present Oct – May, although timing may vary between years. Eggs are laid Jan – early Feb, and chicks are present late Jan – mid May (Hermes *et al.* 1986). Nests are restricted to rocky ridges and cliffs (Hermes *et al.* 1986). Pukeko have been observed to prey on the eggs of the brown noddy, but the severity of this threat is not known.

Black noddy

The black noddy was first recorded within the Norfolk I Group in an illustration by Hunter in 1790 (Hindwood 1965), and was listed as present between 1851 and 1888 (Ramsay in Schodde *et al.* 1983). It was recorded breeding on Phillip I in 1908 (Hull 1910).

We estimate the population of black noddies on Phillip I to be 100–1000 pairs. In 1977, the population on Phillip I was estimated at 1000–10,000 pairs (Fullagar in Schodde *et al.* 1983), but Tarburton (1981) suggested there were only about 30 pairs present in the late 1970's. No banding of this species has been undertaken on Phillip I.

Black noddies nest on Phillip I late Oct – Apr. Eggs are present Nov – mid Mar, and chicks are present Jan – Apr (Schodde *et al.* 1983; Hermes *et al.* 1986). Nests are built from grass, seaweed, leaves, small sticks and excreta, and are constructed on the horizontal branches of tall shrubs and trees, particularly white oaks. They occur in small, scattered groups, principally in the central and lower sections of Long Valley (Fig. 1). Because this species nests arboreally, further regeneration of the forest on Phillip I will enhance the opportunities for nesting.

Blue-grey noddy

The blue-grey noddy was first recorded on Norfolk I between 1851 and 1888 (Ramsay in Schodde *et al.* 1983). The first record of nesting on Phillip I was in 1908 (Hull 1910). Definitive evidence is lacking, but this population appears to have decreased in recent years (Christian 2005). In 1977, it was estimated to be 1000–10,000 pairs (Fullagar in Schodde *et al.* 1983), but 2 years later Tarburton (1981) could find only 15–20 nests. In Nov 2006, no nests were present but courting birds numbered 100–1000 pairs. Widely distributed throughout the southern and central Pacific the species is classified globally as least concern (BirdLife International 2009a). Within Australia, populations occur only on Norfolk and Lord Howe Is, where the subspecies *Procelsterna cerulea albivitta* is regarded as endangered (Garnett & Crowley 2000). No blue-grey noddies have been banded on Phillip I.

The blue-grey noddy is a summer breeder that nests on the ground, usually on exposed cliffs or steep rock faces. Eggs are laid early Oct – early Jan, and chicks are present Oct – mid Mar. Flying young first appear in Jan (Hermes *et al.* 1986). The remains of blue-grey noddies found on Phillip I indicate that this species falls prey to swamp harriers (Hermes *et al.* 1986), but the extent of this predation is unknown. More recently, predation of eggs by pukeko has been observed.

DISCUSSION

Four species of seabirds breeding on Phillip I— Providence petrel, Kermadec petrel, white-naped petrel and flesh-footed shearwater — have small but ecologically significant populations. The population of red-tailed tropicbird is also significant as it is one of the largest breeding colonies of this species in Australia.

Revegetation on Phillip I following the removal of rabbits has greatly benefitted the suite of seabirds that breed there. Soil formation and stabilisation has increased the nesting opportunities for burrowing species. Nesting habitat has been enlarged for those species that traditionally nest in forest or shrubland (e.g., Providence petrel, Kermadec petrel, white-naped petrel, black-winged petrel, flesh-footed shearwater, little shearwater, brown noddy and black noddy). Similarly, the establishment of grasses and other low vegetation has increased nesting sites for those species that prefer open habitats (e.g., wedge-tailed shearwater, Australasian gannet, masked booby and sooty tern), as well as providing concealment for eggs and chicks.

As revegetation continues, those species that nest in open habitats will aggregate onto the headlands where tree cover is absent, but will be otherwise unaffected. Vegetation is unlikely to encroach heavily along cliffs, so cliff-nesting species (e.g., red-tailed tropicbird and blue-grey noddy) are unlikely to be detrimentally affected. Despite the uncertainties, concern that further revegetation will diminish the value of Phillip I for seabirds (DEH 2003) is unfounded, particularly if the existing weed control programme continues. Kikuyu grass, in particular, has the potential to smother burrows and should continue to be eradicated wherever it occurs.

Other, more immediate threats to the seabirds breeding on Phillip I include: (i) for Providence petrel and flesh-footed shearwater, competition for nests sites by the more numerous wedge-tailed shearwater; (ii) for surface-nesting species, predation of eggs and chicks by pukeko; and (iii) for sooty terns, harvesting of eggs. The severity of each of these threats is unknown.

Several species of burrow-nesting seabirds compete for the relatively few burrows that occur on the summit of Phillip I. The extent of these interactions and the fate of the expelled chicks are unknown and warrant investigation. The frequency of observed attacks on Providence petrel chicks by wedge-tailed shearwaters suggests that competition for burrows is a serious threat to the small population of Providence petrels (and possibly flesh-footed shearwaters). In the absence of contrary data, we presume that management intervention to prevent the common species from using these burrows is needed if the rare species are to maintain or expand their populations on the island. Trials should be undertaken to determine if burrows can be fitted with flaps that allow the passage of Providence petrels but prevent the entry of shearwaters. Such devices have been used successfully to minimise interference to Chatham petrel (*Pterodroma axillaris*) chicks by broad-billed prions (*Pachyptila vittata*) (Sullivan & Wilson 2001).

The pukeko was first recorded breeding on Norfolk I in 1888 (Ramsey in Schodde *et al.* 1983). This, or a congeneric species, was present in Polynesian times (Holdaway & Anderson 2001), although the amount of suitable habitat was much less than exists today. Predation by the pukeko is known to be particularly damaging to populations of Kermadec petrel, sooty tern, brown noddy and blue-grey noddy, but may also affect other surface-nesting species such as the white-naped petrel and red-tailed tropicbird. Because of its predatory habits, the pukeko has been regarded as a pest on Norfolk I for several decades at least, having been shot under licence since before 1975 (de Ravin 1975). Despite these control attempts their numbers appear to have increased in recent years. Control by shooting and trapping on Phillip I has also proven ineffective, with more than 40 adult birds present. Also, individuals have been observed flying between Norfolk and Phillip Is, and the population on the main island may now forage on Phillip I. Studies are needed to assess the impact of pukeko on other avian species. Depending on the findings, more stringent control measures may be warranted, on both Phillip and Norfolk Is. As the pukeko is mostly a species of open habitats, maturation of the forest on Phillip I over time may limit its numbers and provide a safe haven for those seabirds able to breed under forest cover.

The number of sooty tern within the Norfolk I Group has been reduced noticeably since settlement (Turner *et al.* 1968). Vast numbers of sooty tern eggs were once harvested and it is thought that this practice has been the cause of population decline, although definitive evidence is lacking. Sooty tern eggs are still legally harvested, but because of increased affluence and enhanced conservation awareness, interest is waning and the number of eggs collected is probably declining. However, there

is no monitoring of the harvest and no assessment of its impact. No attempt has been made to calculate the maximum sustainable harvest or to assess whether this is likely to vary in line with other ongoing pressures on the marine environment. Any previous justification that harvesting of sooty tern eggs was needed to supplement the frugal diet of the inhabitants of Norfolk Island has long since ceased.

Local populations of blue-grey noddy also appear to be declining, for reasons that are unclear. Swamp harriers at times prey heavily on blue-grey noddies and probably take adults and young of several other seabirds breeding on Phillip I. However, swamp harriers are present within the Norfolk I Group only in winter and do not breed there. It is thought that the birds are on migration or post-breeding dispersal from southern Australia or New Zealand to New Guinea or other islands in the south-west Pacific (Schodde *et al.* 1983). Polynesian food remains on Norfolk I include another diurnal raptor, probably the brown goshawk (*Accipiter fasciatus*) and records from the early settlement indicate that this species was present on Phillip I in 1788 (Medway 2002b). Thus, there is no convincing argument for the need to control the numbers of swamp harriers on Phillip I. Future monitoring, however, should assess the level of predation on blue-grey noddies in particular.

The greatest potential threat to the seabirds on Phillip I is the introduction of rodents. Given the relatively high visitation rate to Phillip I by Government employees, fishers and tourists, it would be highly advisable to establish and enforce rigid biosecurity measures. It would also be prudent to establish an initial line of defence on the island should these measures fail. Bait stations loaded with waxed baits containing brodifacoum (or similar second-generation anticoagulant) should be deployed at all landing sites and around all built structures including the 2 huts currently on the island. These baits should be inspected and replenished at regular intervals.

Few places have been as ecologically devastated by the introduction of exotic mammals as Phillip I. Its restoration, through the removal of exotic mammals, the control of exotic weeds and revegetation has been a landmark achievement. Documenting, understanding and promoting the biodiversity benefits of this initiative would not only demonstrate the return on investment, but would also showcase the value of undertaking such ambitious ecosystem restoration projects. The recovery of seabird populations provides an obvious vehicle through which to achieve this. Several of the seabirds that breed on Phillip I have not been adequately studied anywhere in the world, consequently little is known about their ecological requirements. Studies undertaken on Phillip I by local ornithologists and visiting scientists, while extremely useful, have resulted in only rudimentary information being collected. Detailed ecological studies on Phillip I are needed to identify and evaluate threats for at least 5 species—Providence petrel, Kermadec petrel, white-naped petrel, flesh-footed shearwater and blue-grey noddy. These studies should also aim to develop appropriate long-term monitoring protocols for each species. Where practicable, appropriate management action should be undertaken to address any significant threats.

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