SCIENCE FOR CONSERVATION 316

Seabirds of the Kermadec region

Their natural history and conservation

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Department of Conservation
Te Papa Atawhai

Cover: Kermadec petrel. *Photo: Chris Gaskin.*

Science for Conservation is a scientific monograph series presenting research funded by New Zealand Department of Conservation (DOC). Manuscripts are internally and externally peer-reviewed; resulting publications are considered part of the formal international scientific literature.

This report is available from the departmental website in pdf form. Titles are listed in our catalogue on the website, refer www.doc.govt.nz under *Publications*, then *Science & technical*.

ISSN 1177–9241 (web PDF)
ISBN 978–0–478–14926–5 (web PDF)

This report was prepared for publication by the Publishing Team; editing by Sue Hallas and layout by Amanda Todd. Publication was approved by the General Manager, Research and Development Group, Department of Conservation, Wellington, New Zealand.

Published by Publishing Team, Department of Conservation, PO Box 10420, The Terrace, Wellington 6143, New Zealand.

In the interest of forest conservation, we support paperless electronic publishing.

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Abstract

Seabirds are a highly visible component of the natural character of the Kermadec Islands, the Coastal Marine Area (CMA) and across the wider region's waters, and understanding their role within this environment is essential to inform conservation management. This report reviews current knowledge of shearwaters, petrels, boobies, tropicbirds, terns and noddies breeding on the islands, their historic populations and current status, and compares them with respect to nesting, foraging and feeding. Detailed information about the foraging biology of the region's seabird taxa and marine habitat affinities is either fragmentary or non-existent, so this report draws on extralimital subtropical Pacific Ocean studies. Vessel-based seabird observations collected between 1969–1982 and 2004–2008 showing the distribution and occurrence of Kermadec taxa between 5°S and 35°S and 170°E to 170°W are presented. At least forty-two taxa of southern, subtropical and tropical origins are also shown to occur with the region, generally on migration during non-breeding months, although some taxa (e.g. from northern New Zealand offshore islands) occur during breeding periods. The oceanic location of the Kermadec Islands—between tropical and temperate zones, and in an area of relatively high productivity—contributes to their status as a major seabird refuge of international importance. Historical records show that Kermadec waters supported much larger seabird populations. Following successful predator- and pest-control programmes, an increase in seabird numbers is already evident on Raoul Island, the largest island in the group. In this context, the activity and behaviour of all Kermadec seabirds, including breeders, non-breeders and recently fledged birds, must be taken into account when determining the types of human activities permitted within the CMA and the New Zealand Exclusive Economic Zone area around the islands. Emphasis is given to the threats they face on land and sea, and recommendations are provided.

Keywords: Kermadec Islands, seabirds, distribution, occurrence, foraging, feeding, nesting, human activities

Gaskin, C.P. 2011: Seabirds of the Kermadec region: their natural history and conservation. *Science for Conservation 316*. Department of Conservation, Wellington. 71 p.

1. Introduction

The Kermadec Islands are largely uninhabited, oceanic, subtropical islands lying midway between New Zealand's North Island and Tonga (Fig. 1). Their isolation and location in an area of relatively high productivity (Arnold 2004) have made the islands a major seabird[1] refuge of international importance (Taylor 2000a). Most recent estimates place the seabird population of the islands (total area = 3383 ha) at 10–15 million birds (Taylor 2000a,b; Greene et al. 2004; Veitch et al. 2004)—equivalent to the estimated breeding population in the entire northwestern Hawaiian island chain or in all the USA-managed islands that are part of the new Pacific Remote Islands Marine National Monument (E. Flint, U.S. Fish and Wildlife Service, pers. comm., 15 April 2009). Raoul Island, by far the largest island in the Kermadec group at 2943 ha, was almost devoid of seabirds by the end of the 20th century owing to predation, harvesting and habitat loss following human arrival (Merton 1970). It is conceivable, therefore, that Kermadec waters previously supported much larger seabird populations. Early indications are that populations are likely to increase following predator- and pest-control programmes on Raoul and Macauley Islands.

Seabirds are mostly long lived (20–60 years), with a delayed breeding age of up to 10 years, multi-year pair bonds, small clutch sizes (often only one egg) and extended chick-rearing periods (often up to 3 months) (Taylor 2000a). They breed on islands but spend most of their lives at sea, foraging at the surface or diving deep for prey. Essentially marine creatures, they have evolved to exploit the vast, rich and complex marine environment, possessing unique physiological and morphological adaptations (Schreiber & Burger 2002)—what Gaston (2004) dubbed 'the seabird syndrome'. Nine of the 14 Kermadec seabird taxa are tropical seabirds, with the islands being the southernmost limit of their range; two are primarily subtropical seabirds; and the remaining three share close temperate affinities (Table 1). This strong tropical bias constitutes a major point of difference from the rest of New Zealand's seabird fauna. Eight of the Kermadec seabird taxa are shown in Fig. 2, while three others (Kermadec petrel, red-tailed tropicbird and grey noddy) are shown elsewhere in the report (see cover and section 4.1, Fig. 12). All these seabirds utilise the Kermadec Islands Coastal Marine Area (CMA): for foraging and feeding; for gathering and resting prior to flying to colonies; for bathing; or as stop-off points during the passage between colonies and foraging grounds far offshore. This report looks at the seabirds that breed on the Kermadec Islands and those that visit the region, and investigates their ecology. While a number of the resident seabirds are pelagic feeders and forage over long distances (up to 3000 km) during breeding, the complex bathymetry of the region means that most Kermadec seabirds can find prey within easy commuting range of breeding colonies. For some seabirds, a large proportion of their food is captured in waters immediately surrounding the islands. In fact, seabirds are a major and highly visible component of the natural character of the islands, the CMA and adjacent waters. In this context, the activity and behaviour of all Kermadec seabirds including breeders, non-breeders and recently fledged birds, must be taken into account when determining the types of human activities permitted within the CMA.

[1] 'Seabirds' include storm petrels, shearwaters, petrels, giant petrels, albatrosses, gannets, boobies, tropicbirds, frigatebirds, shags (or cormorants), gulls, terns and noddies. Scientific names for taxa mentioned in this report are provided in Appendix 1.

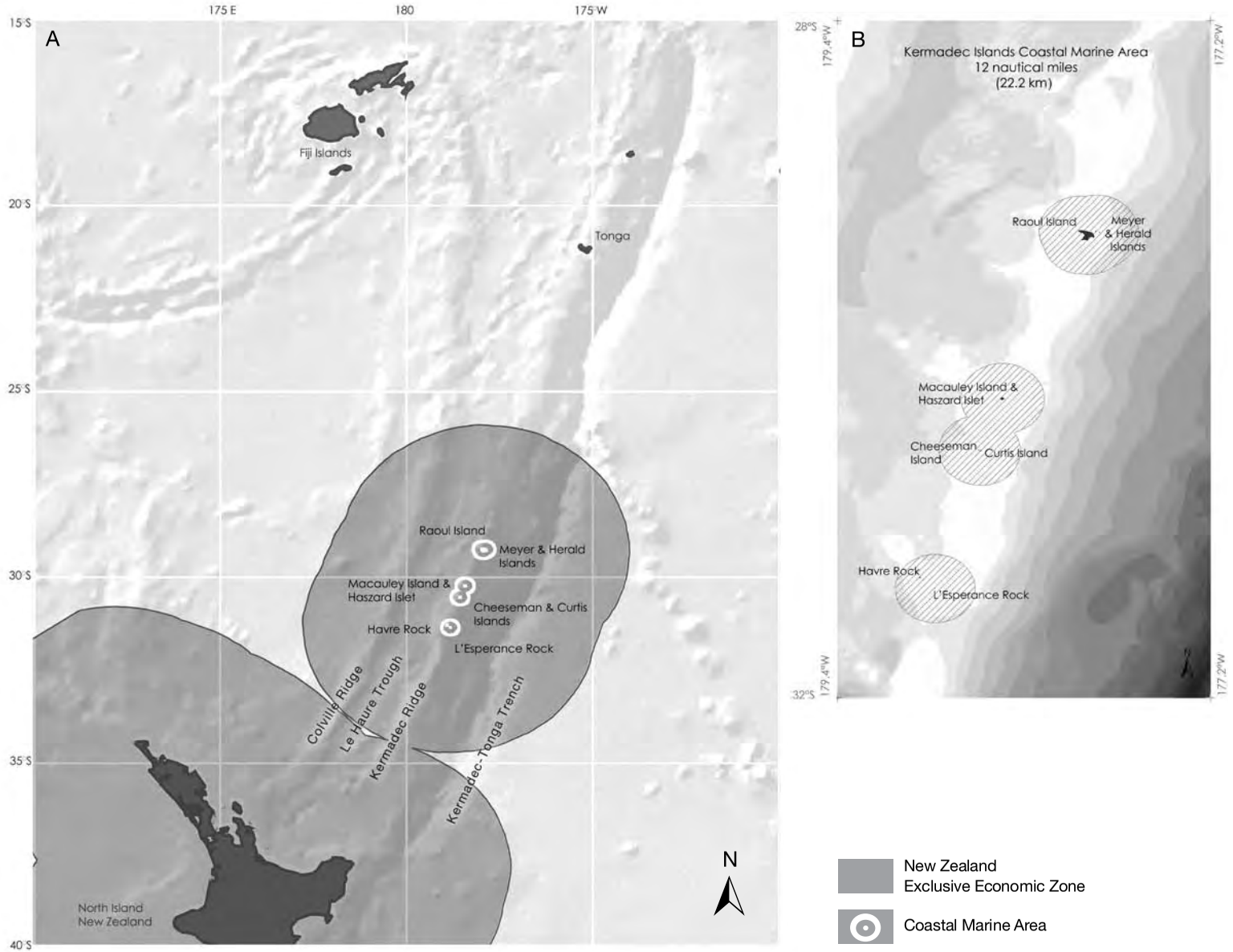

Figure 1. Maps showing A. the location of the Kermadec Islands and New Zealand's Exclusive Economic Zone (shaded area), and B. the Kermadec Coastal Marine Area (hatched area).

Figure 2. Eight seabird taxa found on the Kermadec Islands: A. white-necked petrel (*photo: Peter Harrison ©Seabirds Handbook Project*); B. wedge-tailed shearwater (*photo: ©Hadoram Shirihai / The Tubenoses Project*); C. Kermadec storm petrel (*photo: Gareth Rapley*); D. white-bellied storm petrel (*photo: ©Hadoram Shirihai / The Tubenoses Project*); E. sooty tern (*photo: Karen Baird*); F. masked (Tasman) booby (*photo: Chris Gaskin*); G. black-winged petrel chick (*photo: Karen Baird*); and H. Kermadec little shearwater (*photo: Karen Baird*).

Table 1. Seabirds confirmed breeding in the Kermadec region (Taylor 2000a,b; Veitch et al. 2004), including zonation/geographical affinities, IUCN rank (www.iucnredlist.org; viewed 27 March 2011) and New Zealand threat classification (Miskelly et al. 2008). Species codes are from the NOAA seabird surveying programme.

COMMON NAME	CODE	ZONATION*	IUCN† RANK	NEW ZEALAND THREAT CLASSIFICATION‡
Procellariiformes				
Wedge-tailed shearwater	SHWT	Tr, ST	LC	Relict (B) [RR, SO]
Kermadec little shearwater	SHKL	ST, Te	V	Relict (B) [IE; RR]
White-naped petrel	PEWN	ST	V	Relict (B) [IE; OL]
Kermadec petrel	PEKE	Tr, ST	LC	Relict (A) [SO]
Black-winged petrel	PEBW	ST, Te	LC	Not threatened [De, Inc; RR; SO]
White-bellied storm petrel	SPWB	ST	V	Nationally endangered (B(1/1)) [DP; SO]
Kermadec storm petrel	SPKE	ST, Te	Data def.	Nationally critical (A) [IE; OL]
Pelecaniformes				
Masked (Tasman) booby	BOTA	Tr, ST	V	Nationally endangered (B(1/1)) [RR; St; TO]
Red-tailed tropicbird	TBRT	Tr, ST	LC	Nationally endangered (B(1/1)) [RR; SO; St]
Charadriiformes				
Grey noddy (grey ternlet)	NOBG	Tr, ST	LC	Naturally uncommon [RR; SO]
New Zealand sooty tern	TESO	Tr, ST	V	Naturally uncommon [DP; RR; SO]
Black (white-capped) noddy	NOBL	Tr, ST	LC	Naturally uncommon [RR; SO]
Brown (common) noddy	NOBR	Tr, ST	LC	Coloniser [OL; SO]
White tern	TEWH	Tr, ST	LC	Nationally critical (A) [OL; SO]

* Tr = tropics; ST = subtropics; Te = temperate.

† V = Vulnerable; LC = Least Concern; Data def. = Data deficient.

‡ B = Threatened; B.1 = Nationally Critical; B (1/1) = Nationally Endangered; De = Designated; DP = Data Poor; IE = Island Endemic; Inc = Increasing; OL = One Location; RR = Range Restricted; SO = Secure Overseas; St = Stable; TO = Threatened Overseas.

2. Background

2.1 The Kermadec Islands

The Kermadec Islands (Raoul, Macauley, Curtis and Cheeseman Islands, and L'Esperance Rock, with their associated islets and stacks) are located between latitudes 29°S (Raoul Island) and 32°S (L'Esperance Rock). They are the emergent summits of a volcanic arc and the associated subduction system that is aligned north-northeast and stretches from temperate New Zealand to just south of Samoa (Wright et al. 2006). This major oceanographic feature includes the Kermadec–Tonga Trench (with a maximum water depth of 10 800 m, making it the world's second-deepest trench), the Kermadec–Tonga Ridge and the Havre Trough (maximum water depth of 4512 m) (Fig. 1). The waters around the islands have mean surface-temperature ranges of 18–23.7°C at the northern end of the island chain and 16.8–23°C at L'Esperance Rock (Francis et al. 1987), with extremes of 16°C and 24.8°C recorded at Fishing Rock, Raoul Island, between November 1998 and May 2007 (A. Shaw, NZ MetService, pers. comm., 24 July 2008). This temperature range places the islands' waters outside Ashmole's (1971) definition of tropical waters: ocean areas with sea-surface temperatures ≥ 23°C. However, the islands are still subject to a strong tropical influence.

The Kermadec region's marine biota comprises a mix of tropical, subtropical, temperate and endemic species (Brook 1999). The isolation of the Kermadec Islands is highlighted by their paucity of land birds, with only a handful (five species) having been confirmed as native species in the 19th century. Various waders and two cuckoos—the long-tailed cuckoo and the shining cuckoo—stop-off during their migration; other birds have turned up as vagrants. Through the 20th century, a further eight species adopted the islands as their home, some possibly arriving as passengers on boats.

Polynesians crossing into the southern ocean in search of new lands were the first to discover these islands (Anderson 1980). Raoul Island, or 'Sunday Island' as it was known to the next wave of visitors, received the greatest attention; Macauley, with its difficult landings, was less visited; and inhospitable Curtis and Cheeseman Islands and L'Esperance Rock (French Rock) were very rarely visited (Johnson 1995). Human-derived impacts on the fauna and flora of the Kermadec Islands followed a common pattern: greatest on Raoul, less so on Macauley and minimal on the others, as discussed in section 4.5.4. Specifically, following human impacts, including the introduction of mammalian predators, most of the seabird taxa suffered catastrophic declines on Raoul Island and to a lesser extent on Macauley Island (Veitch et al. 2004).

2.1.1 Raoul Island

Raoul Island (2938 ha) is the largest in the group. It is roughly triangular shaped, approximately 10 km long and 7 km wide, and rises to 516 m a.s.l. at Mt Moumoukai (Fig. 3). Its topography consists of a steep-sided, central caldera with major ridges to the west and south, from which run sharply dissected ridges and ravines (Veitch et al. 2004). The island is mostly covered in a forest dominated by the endemic Kermadec pōhutukawa.

The number of seabirds breeding on Raoul prior to first human arrivals is difficult to estimate, both with respect to taxonomic diversity and total population size. It is most likely that seabird populations would have been considerably larger than estimates made in the early 20th century (Iredale 1910, 1913, 1914; Oliver 1912). It is also likely that one or even both storm petrel taxa, the Kermadec little shearwater and the black noddy were formerly breeding on the island, although there is no evidence to support this. It is difficult to determine where seabirds were breeding, with a patchy distribution possible (G. Taylor, Department of Conservation (DOC), pers. comm., 11 March 2010). From historical accounts (Cheeseman 1889, 1891; Iredale 1910, 1913, 1914; Bell 1911, 1912; Oliver 1912; Bacon 1957; Sorenson 1964; Merton 1970), we find that seabirds were once so plentiful on Raoul that chicks and eggs were harvested for food by settlers, visiting sailors and even scientists up to the 1930s (Iredale 1910; Oliver 1930; Straubel 1954), and the down and feathers of young birds were used to stuff pillows and mattresses (Large 1888). These effects, in addition to those wrought by the rats, feral cats, and even goats, dogs and pigs that settlers and visitors deliberately or unwittingly introduced, meant that by the end of the 20th century, most of the seabird colonies had disappeared from the forest, ridge crests, cliffs and terraces, above headlands or along beaches (Veitch et al. 2004). Any attempts by petrels and shearwaters to breed failed, although it is possible that a few red-tailed tropicbirds continued to nest on remote cliff ledges. Sooty terns persisted in small colonies on the northern beaches in the 1990s, and each year a few white terns were seen along the southern coasts (Veitch et al. 2004). Of the native land bird species, only three species (tūī, kingfisher and pūkeko) remained; the spotless crakes and Kermadec red-crowned parakeets were to be found only on the nearby Herald Islets (Merton 1970).

A long-term government commitment to pest-animal control has begun to reverse these massive losses. First, goats were eliminated during 1972–1984 by hunters of the former New Zealand Forest Service; then, rats and feral cats were eradicated by teams from DOC by 2003. At the time of writing, Raoul Island, along with the rest of the Kermadec Islands, is at the forefront of international efforts to restore seabird populations and save threatened species. In a move to speed up the re-colonisation of seabirds, DOC staff have installed three broadcast systems on headlands (see Fig. 3), playing a variety of petrel calls at different times of the year—a successful technique for attracting prospecting seabirds (G. Taylor, DOC, pers. comm., 21 April 2008), particularly younger birds, to establish colonies at or near speaker locations. The longer term response of the island to the removal of predators is the subject of important ecological research.

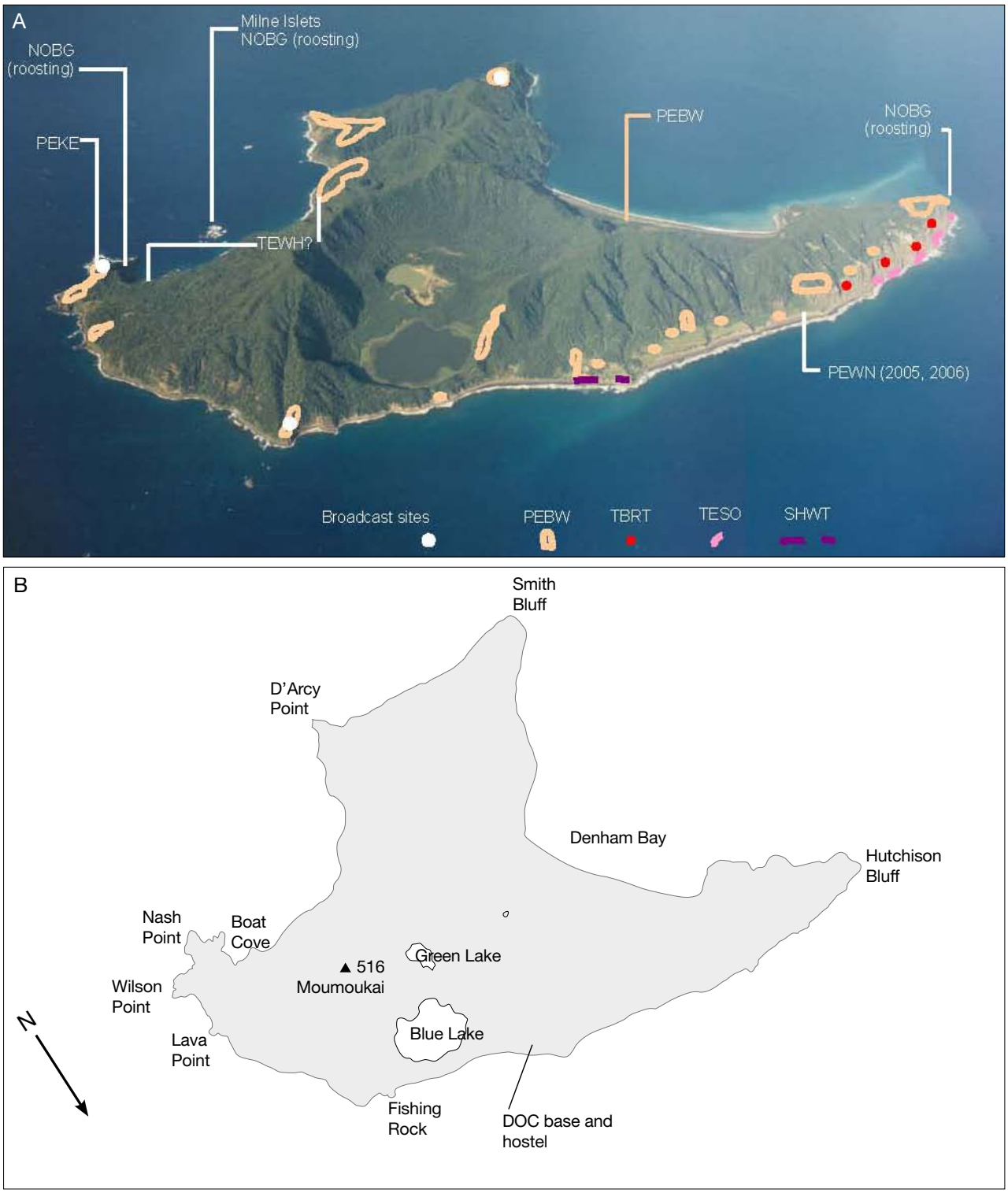

Figure 3. Raoul Island. A. Aerial photograph, viewed from the northwest—white circles denote the location of seabird broadcast systems; B. Diagram showing key features mentioned in the text (for a more detailed map, see www.doc.govt.nz/kermadecmap); and C. Key for species codes (see Table 1).

2.1.2 Herald Islets and Meyer Islands

The Herald Islets (Fig. 4) are located a few kilometres to the northeast of Raoul Island, and comprise eight islands and a number of smaller stacks large enough to sustain vegetation (totalling c. 50 ha). The larger islands, North and South Meyer, and Napier Island, have areas of forest over their summits and down the western slopes, with pōhutukawa, ngaio, karaka and parapara as the dominant, if stunted, trees. There is little understorey owing to the extent of bird burrowing: seabirds burrow or nest in every available, suitable place on these steep islands. Only the sheer cliff faces are free from breeding seabirds. The islands are all free of introduced predatory or browsing mammals (Veitch et al. 2004), and it is possible to experience something of what Raoul was like in the pre-human past and could be again in the future. During the day, petrels, tropicbirds, terns and noddies in their thousands wheel in the sky, fly back and forth across ridges and cliff faces, take off and land, calling most of the time. Walking about the island requires extreme care so as not to step on fragile burrows, birds, eggs and chicks. At night, the sounds continue as incoming shearwaters make landfall. Differences in timing of breeding, nesting habitat and migration/dispersal following breeding allow this diversity of surface-, burrow- and tree-nesting species to inhabit such a small area (Merton 1970).

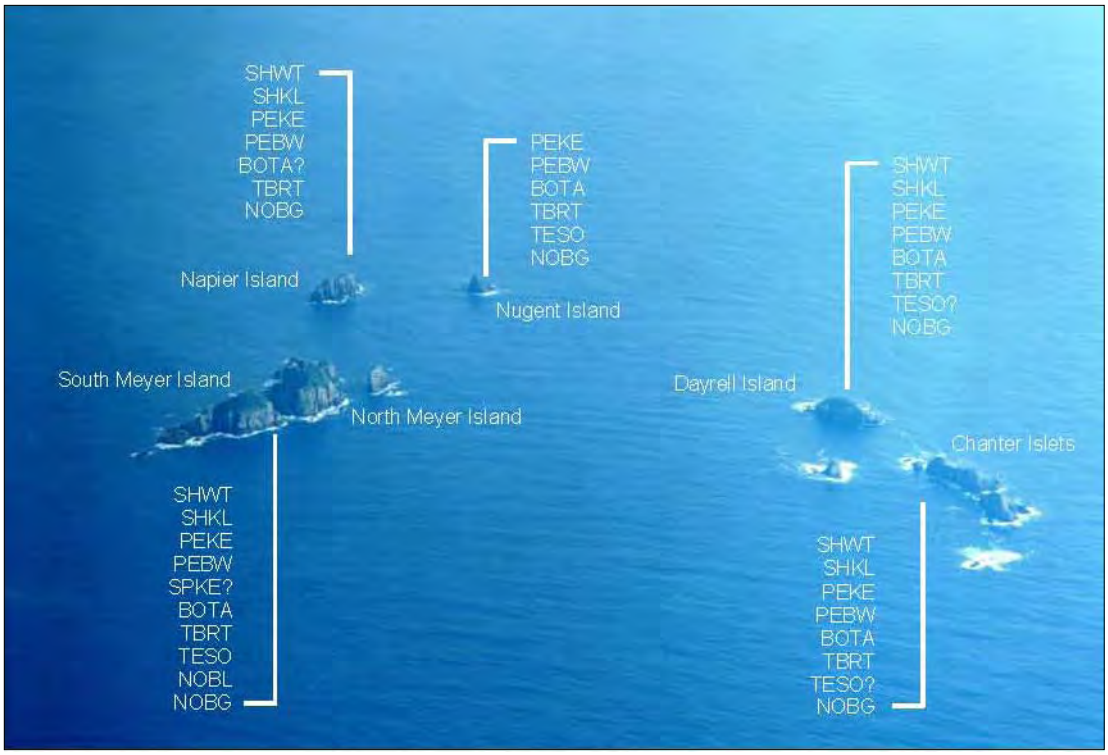

Figure 4. Aerial photograph of the Meyer Islands (left) and Herald Islets (right), taken from the south. See Table 1 for species codes.

2.1.3 Macauley Island and Haszard Islet

Macauley Island (306 ha) is 108 km south-southwest of Raoul Island. It is a roughly circular plateau, sloping gently from Mt Haszard (238 m a.s.l.) to the southeast, and bordered on all sides by steep cliffs of pumiceous tuff usually over 60 m high (Fig. 5). The surface of Macauley is cut by numerous steep-walled erosion gullies (Veitch et al. 2004). Evidence of visits by Polynesian voyagers was provided by the presence of the Pacific rat. When the first Europeans came to the island in 1788, they described it as having 'many Trees, Shrubs & grass upon it', around 'which the Sea broke in a dreadful surf' (Smyth 1788). During the early 19th century, goats and pigs were released, ostensibly to provision visiting whalers who knew the island as 'Green Island'. When the *Australian* visited in 1836, the crew found the island honeycombed with seabird burrows, and the presence of a 'few stunted trees and a little wild parsley and other herbage on the most elevated part' (Rhodes 1836: 36, cited in Straubel 1954). It also found an abundance of goats and pigs, noting that the pigs were probably 'subsisting on the flesh of aquatic birds' (Straubel 1954). The pigs had long since disappeared when the goats, which had trampled seabird burrows and destroyed vegetation cover, were eradicated during 1966–1970. In 1988, it was estimated that up to 5.2 million seabirds (2.6 million pairs) were breeding on Macauley Island (Taylor & Tennyson 1988). By 2006, 18 years later, rats were eradicated. Today, with pest eradication complete, restoration of the island's ecology is underway.

Macauley Island's little outlier, Haszard Islet, lies 250 m to the east, across Wildlife (Boat) Passage (Veitch et al. 2004). It is entirely cliff bound, and access to the vegetated summit has been possible only by helicopter. The island appears to have always been predator free. A visit in 2006 by seabird biologist M. Imber and K. Baird (Programme Manager Kermadec Islands, DOC) resulted in the discovery of the breeding site for the Kermadec storm petrel, an endemic species recognised in the 4th edition of the Ornithological Society of New Zealand's (OSNZ's) *Checklist of the Birds of New Zealand* (OSNZ Checklist Committee 2010).

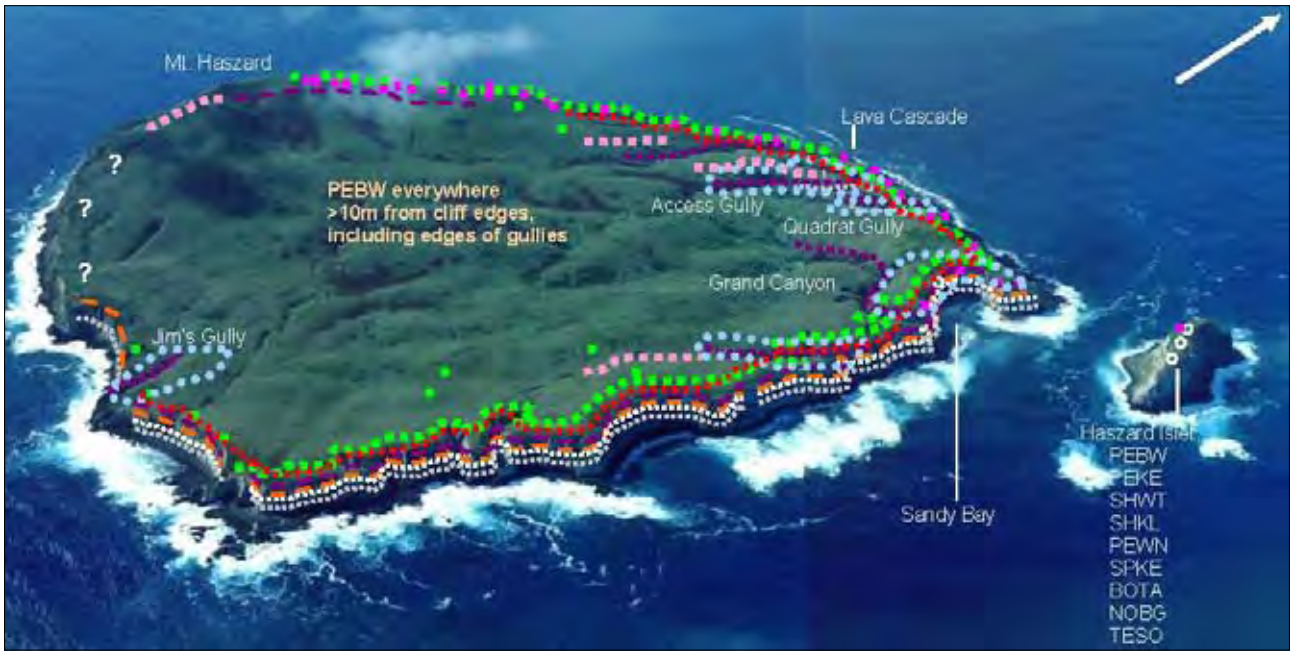

Figure 5. Aerial photograph of Macauley Island and Haszard Islet, taken from the southeast, showing the locations of seabird nesting areas found on surveys undertaken in 1988 and 2002. White arrow points north. See Fig. 3C and Table 1 for species codes.

2.1.4 Curtis and Cheeseman Islands

Curtis Island (52 ha) is 37 km south-southwest of Macauley Island. Steep cliffs rise 100–130 m to a gently undulating summit ridge that surrounds a 6-ha crater (Fig. 6). Curtis is an active volcano with boiling mudpools and sulphur-encrusted fumaroles in its crater, and steam issuing from a few points on the upper slopes of the island (Veitch et al. 2004). The slopes above the shoreline and the broad summit ridge are covered with native ice plant, sedge, grasses and herbaceous plants, with ferns and low shrubs in places. There is little vegetation on the crater floor (Sykes et al. 2000). All available soil is extensively honeycombed by petrel burrows (G. Taylor, DOC, pers. comm., 5 March 2009).

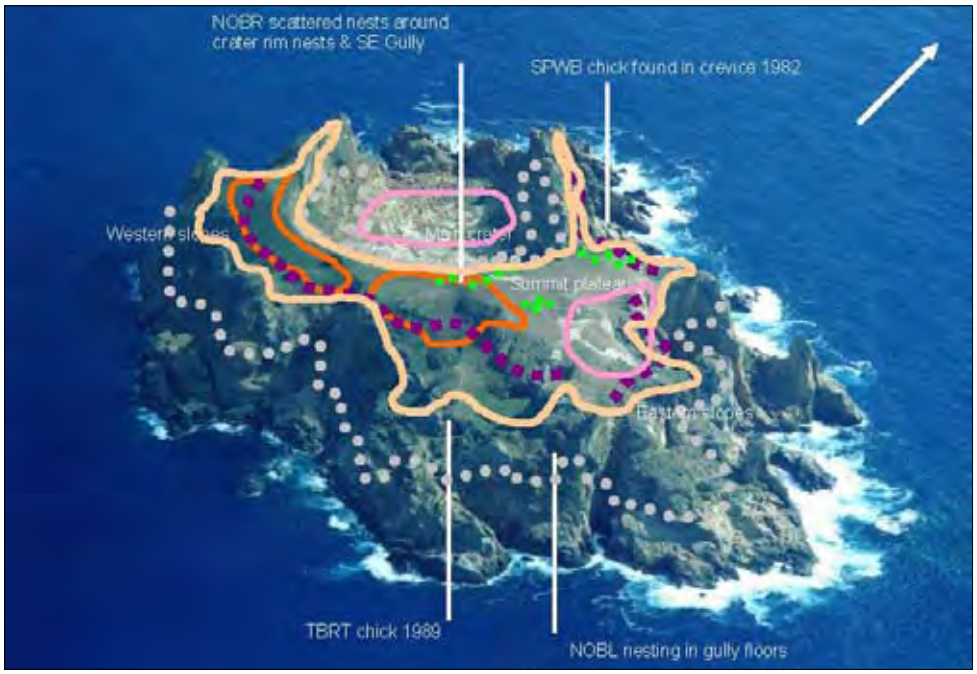

Figure 6. Aerial photograph of Curtis Island, taken from the south showing the locations of seabird nesting areas. White arrow points north. See Fig. 3C and Table 1 for species codes.

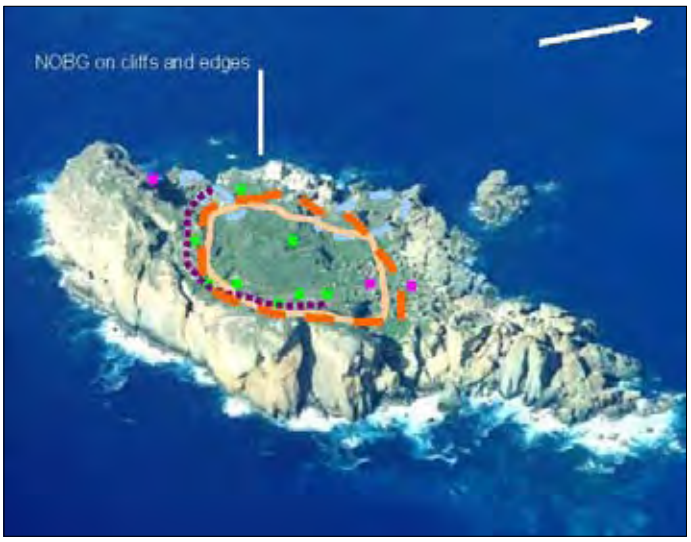

Figure 7. Aerial photograph of Cheeseman Island, taken from the east showing the locations of seabird nesting areas. White arrow points north. NOBG = grey noddy.

Cheeseman Island (7.6 ha) lies to the west of Curtis Island, separated from it by the 570-m wide Stella Passage. It is basically a large, irregular-shaped rock, with inaccessible cliffs up to 60 m high around most of the island (Fig. 7). The upper slopes include a small central gully and are covered by ice plant, sedge, herbaceous plants and grasses (Sykes et al. 2000; Greene et al. 2004).

Curtis Island appears to have received the most visitors of all the southern Kermadec Islands, largely because its volcanic activity has appealed to the curious. Goats were liberated onto Curtis in 1887 but these did not survive (Large 1888). Both islands remain rat free. There are reports of only two parties having landed on Cheeseman Island: scientists and New Zealand Wildlife Service staff in 1970 from the sea (Sykes et al. 2000), and scientists in 2002 by helicopter (Greene et al. 2004).

2.1.5 L'Esperance Rock

Also known as 'French' or 'Brinds Rock', L'Esperance Rock (5 ha) is the remnant of an extinct volcano rising to 46 m a.s.l. (Figs 8 & 9). It is 97 km south-southwest of Curtis Island and is the southernmost of the Kermadec Islands (Veitch et al. 2004). The rugged islet has only six vascular plants recorded, with native ice plant dominant (Sykes et al. 2000).

In 1793, Admiral D'Entrecasteaux, having sighted this 'large rock', was 'soon surrounded by a great number of sea-fowl, among which we noticed many boobies and gulls [noddies or terns]'. He 'distinguished on the most prominent points a whiteness, which we ascribed to their [seabirds'] excrement' (Labillardière 1971: 330–331).

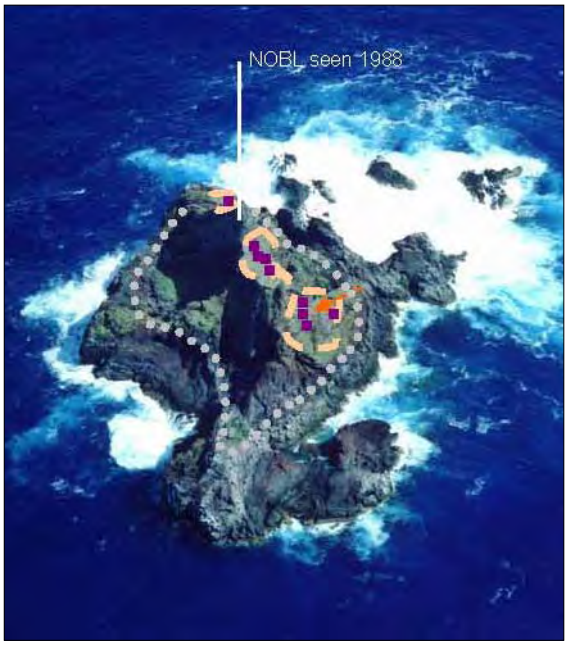

Figure 8. Aerial photograph of L'Esperance Rock, taken from the east showing seabird nesting habitat. The orange triangle marks the location of the former fuel depot, destroyed in the February 2011 cyclone. NOBL = black (white-capped) noddy.

Figure 9. View of the eastern side of L'Esperance Rock from the sea, with grey noddies in flight. *Photo: Chris Gaskin*.

2.2 Legal status of seabirds and the Kermadec Islands

All New Zealand seabird taxa (except southern black-backed gulls) are protected by the Wildlife Act 1953 No. 31 and its subsequent amendments throughout New Zealand and its Exclusive Economic Zone (EEZ), which extends 200 n.m. (320 km) offshore (MfE 2005). In addition, New Zealand seabirds nesting on offshore islands administered by DOC have further legal protection under the Reserves Act 1977 (Taylor 2000a). New Zealand is also a party to the international Convention on Migratory Species of Wild Animals, which came into force in New Zealand on 1 October 2000 (www.cms.int/documents/convtxt/cms_convtxt.htm; viewed 14 December 2009). All islands in the Kermadec archipelago form the Kermadec Islands Nature Reserve, and surrounding waters out to the territorial limits (12 n.m.), form the Kermadec Islands Marine Reserve.

3. Information sources and methodology

This report adopts the *Checklist of the Birds of New Zealand* (OSNZ 2010), the *New Zealand Threat Classification System manual* (Townsend et al. 2008) and the International Union for Conservation of Nature *IUCN Red List of Threatened Species*™ (www.iucnredlist.org; viewed 27 March 2011) for all bird classification; that is, taxonomic and conservation status, and scientific and common names. All available published and unpublished information on seabird breeding and behaviour was reviewed for this report. Notable published references include MacGillivray (1854), Iredale (1910, 1914), Oliver (1910, 1912, 1930, 1955), Merton (1970), Taylor & Tennyson (1994), Taylor (2000a,b), Greene et al. (2004) and Veitch et al. (2004). The following reports produced by the now-defunct Wildlife Service and by DOC, including unpublished material, were also used: Bell (1970), Taylor & Tennyson (1988) and Greene et al. (2004). Accounts (cited as 'pers. comm.') from G. Taylor, M. Imber, P. Scofield, T. Greene, B. Bell, C. Miskelly and R. Veitch were valuable sources of information with respect to seabird breeding and early island eradication work.

Information specifically about Raoul Island was drawn from DOC *Raoul Island Thirdly Reports*, hut logbooks and the 'blue' bird notebook kept at the DOC base hostel. In addition, recent investigative work has been undertaken by DOC Raoul Island staff on sooty tern colonies (colony counts, i.e. colony location and size) from 2005 to 2009. Further investigative work by K. Baird, M. Hauber and S. Ismar on the black-winged petrel and wedge-tailed shearwater in May 2007, and by S. Ismar on the black-winged petrel and wedge-tailed shearwater, and C. Gaskin (general search) in April 2008, located a number of new breeding sites. DOC staff and volunteers have also marked burrows and recorded their locations during weeding operations.

At-sea observations serve to locate seabirds spatio-temporally across the world's oceans by species or nearest taxon, although lack of standardisation of data-collection methodology can frustrate attempts to estimate seabird density (Spear et al. 2004; Bartle & Spear 2005). Importantly, at-sea observations provide insights into the behaviour and biology of individual species, community composition (because seabird breeding communities almost always differ from seabird feeding communities) and interspecific interactions (Ballance 2008). Data sources for ship-based seabird observations included here are notes made by J. Jenkins during inter-island voyages (between New Zealand's North Island and Fiji, American Samoa, Samoa and Tonga) as master aboard Union Steam Ship Company vessels (Jenkins 1979b), notes made by C. Miskelly during a yacht voyage between New Zealand and Tonga in 1982, and information from recent surveys (2004–2008), in the main from vessels servicing the DOC base at Raoul Island (Table 2).

Table 2. Summary of at-sea observations and survey data used to assess patterns in the distribution of seabirds in the south Pacific Ocean, 15°–35°S, 170°E–170°W, from 1970 to 2008.

DATASET	PRINCIPAL OBSERVER	VESSEL	YEARS	SEASONALITY
Auckland-Fiji-American Samoa-Samoa-Tonga-Auckland: inter-island	Jenkins	Various	1970–1979	Year round
Auckland-Tonga	Miskelly	*Derwent*	1982	May
Tauranga-Kermadec-Tauranga	Imber	MV *Southern Salvor*	2004	November
Tauranga-Kermadec-Tauranga	Gaskin	RV *Braveheart*	2006	January
Auckland-Kermadec-Auckland	Baird	Various (HMNZS *Te Kaha, Resolution*; MV *Southern Salvor*)	2006–2008	March, April, June, July, August, October, November
Auckland-Kermadec-Auckland	Gaskin	HMNZS *Canterbury*	2008	April
Wellington-Kermadec-Wellington	Gaskin	RV *Tangaroa*	2007	May
Kermadec Islands/Ridge east-west transects	Gaskin	RV *Tangaroa*	2007	May
Tauranga-Kermadec-Tauranga	Baird	RV *Braveheart*	2008	November

Jenkins' notes (held at the Museum of New Zealand Te Papa Tongarewa) list observations with information recorded as follows: cruise number; logbook number; page number; date; time (local); latitude; longitude; bearing; ship speed; wind direction; wind speed; barometric pressure; and sea-surface temperature (early records are in Fahrenheit, later in Celsius). He recorded species names, number of birds seen, including groups of birds, and behaviour. For the most part, Jenkins logged his observations hourly. More frequent entries were made when he observed something of significance (for example, large flocks of shearwaters on migration south, or mixed feeding flocks). Observations of a more general nature were also included.

The recent (2004–2008) at-sea observations were made from the foredeck or flying bridge during most daylight hours, as conditions allowed. Continuous sightings data (i.e. date, time, species/taxa code, number of birds, including comments on behaviour and plumage, if noteworthy) were obtained by using the forward quadrant method, either 90° (single observer) or 180° (two or more observers), although observers maintained a 360° watch, where possible. Single-observer data were recorded in notebooks, with position and time logged using a handheld GPS device (waypoints every 10 minutes, with additional points taken for significant sightings). The content was downloaded into an Excel spreadsheet at the end of each day. A log of sighting conditions (i.e. wind direction and speed, sea conditions, overhead conditions, observer position on vessel), effort (i.e. record of time on- and off-watch) and sightings together with field notes was entered into a laptop computer together with the GPS data. Information on foraging behaviour in inshore waters (i.e. the Kermadec Islands CMA) was gained principally while undertaking seabed mapping aboard RV *Tangaroa*, including crossing the Kermadec Ridge repeatedly. The mapping that relates directly to the Kermadec Islands CMA and nearby waters is shown in Fig. 10 (the relevant region is denoted the Kermadec Study Area).

All at-sea seabird data collected between 1970 and 2008 were combined into a single database for an area of the South Pacific Ocean (15°–35°S, 170°E–170°W) using Excel spreadsheets. Data were entered under common categories: cruise number; logbook number (Jenkins); page number (Jenkins); waypoint number (Gaskin, Baird); date; time (local); latitude; longitude; bearing (Jenkins); ship speed (Jenkins); wind direction; wind speed; sea condition (Gaskin, Baird); barometric pressure (Jenkins); sea-surface temperature; seabirds named to species or nearest taxon; number of birds seen; groups of birds; and behaviour. Two separate worksheets were created: one for all observations of all taxa, the other for sightings of Kermadec-breeding seabirds.

Data extracted from the database were mapped using ArcMap 9.1 to show spatial and temporal variability during two seasons: the austral summer (November–April) and winter (May–October). The seasonal distributions for all 14 seabird taxa breeding in the Kermadec Islands are presented in Appendix 2. Also, best available breeding colony data and estimates of breeding populations from Taylor (2000a,b), Greene et al. (2004), Veitch et al. (2004) and recent surveying are included for each species (Fig. 11).

In the absence of any data on the diets of Kermadec Islands' seabirds, comparisons here are drawn with extralimital studies, as summarised in Marchant & Higgins (1990a,b) and Higgins & Davies (1996). Publications providing information included Ashmole & Ashmole (1967) (Christmas Island); Harrison et al. (1983), Harrison & Seki (1987) and Harrison (1990) (all Hawaiian Islands); Ballance et al. (1997) (tropical Pacific Ocean); Ballance & Pitman (1999) (tropical oceans); Jaquemet et al. (2004) (Reunion Island, Indian Ocean); Spear et al. (2007) (eastern tropical Pacific Ocean); Weimerskirch et al. (2005) (Mozambique Channel); and Weimerskirch (2007) (tropical seabirds).

Data on long-lining effort for tuna and swordfish in FMA10 were supplied by Information Management Group, Ministry of Fisheries (MFish), as the latitude and longitude at which each long-line was set for October 2001 – September 2007. These data were mapped to investigate whether the occurrence of tuna, swordfish and other large predatory fish might indicate potential foraging areas for seabirds (as opposed to reporting on incidental capture of seabird species in commercial fisheries, as in, for example, Baird & Smith (2007).

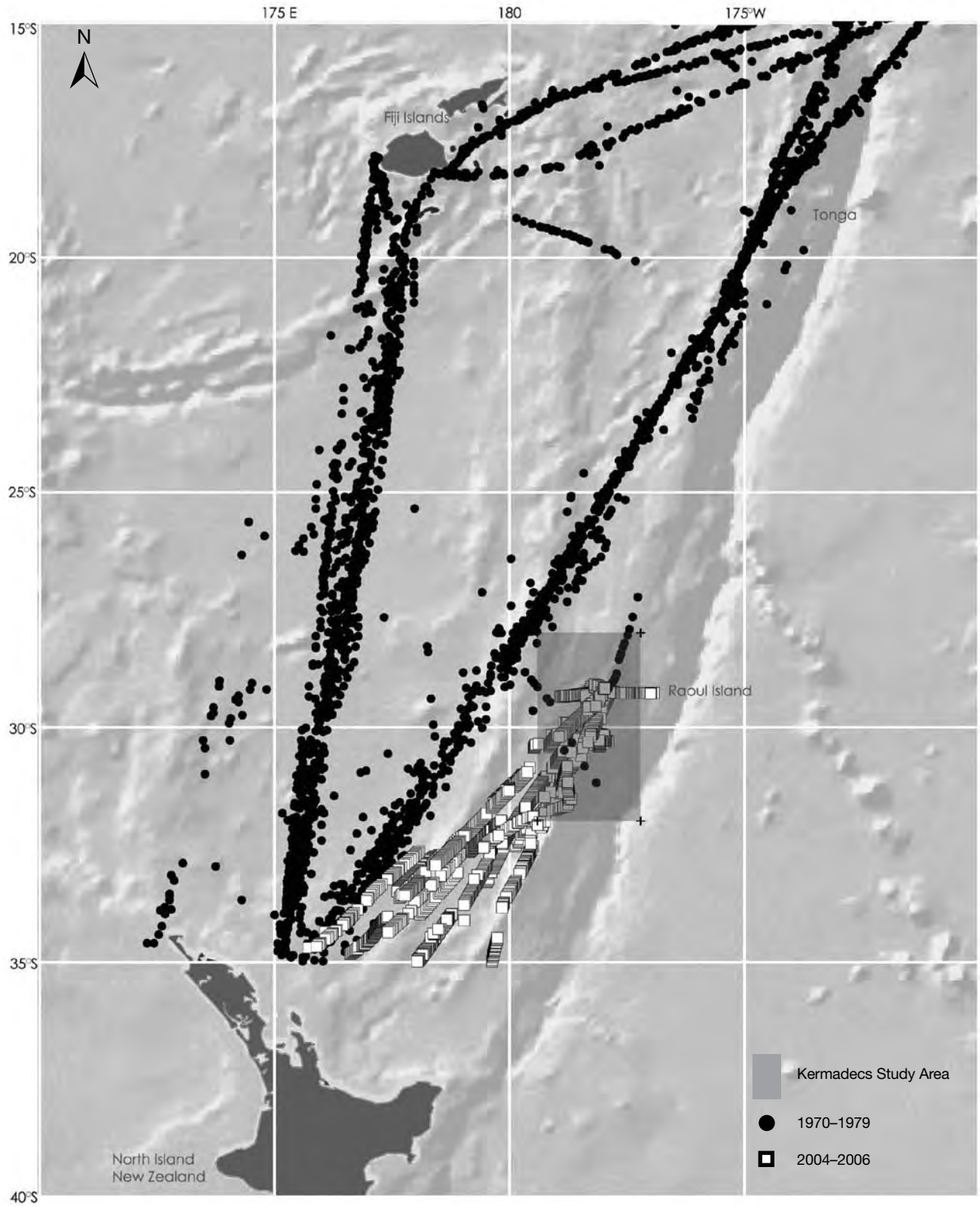

Figure 10. The distribution of at-sea surveying effort for the south Pacific Ocean, 15°–35°S, 170°E–170°W, during 1970–1979 (dots) and 1982, 2004–2006 (squares). The shaded rectangle is the Kermadecs Study Area. Each symbol represents a data entry location, the data being number of both seabird taxa and individual birds.

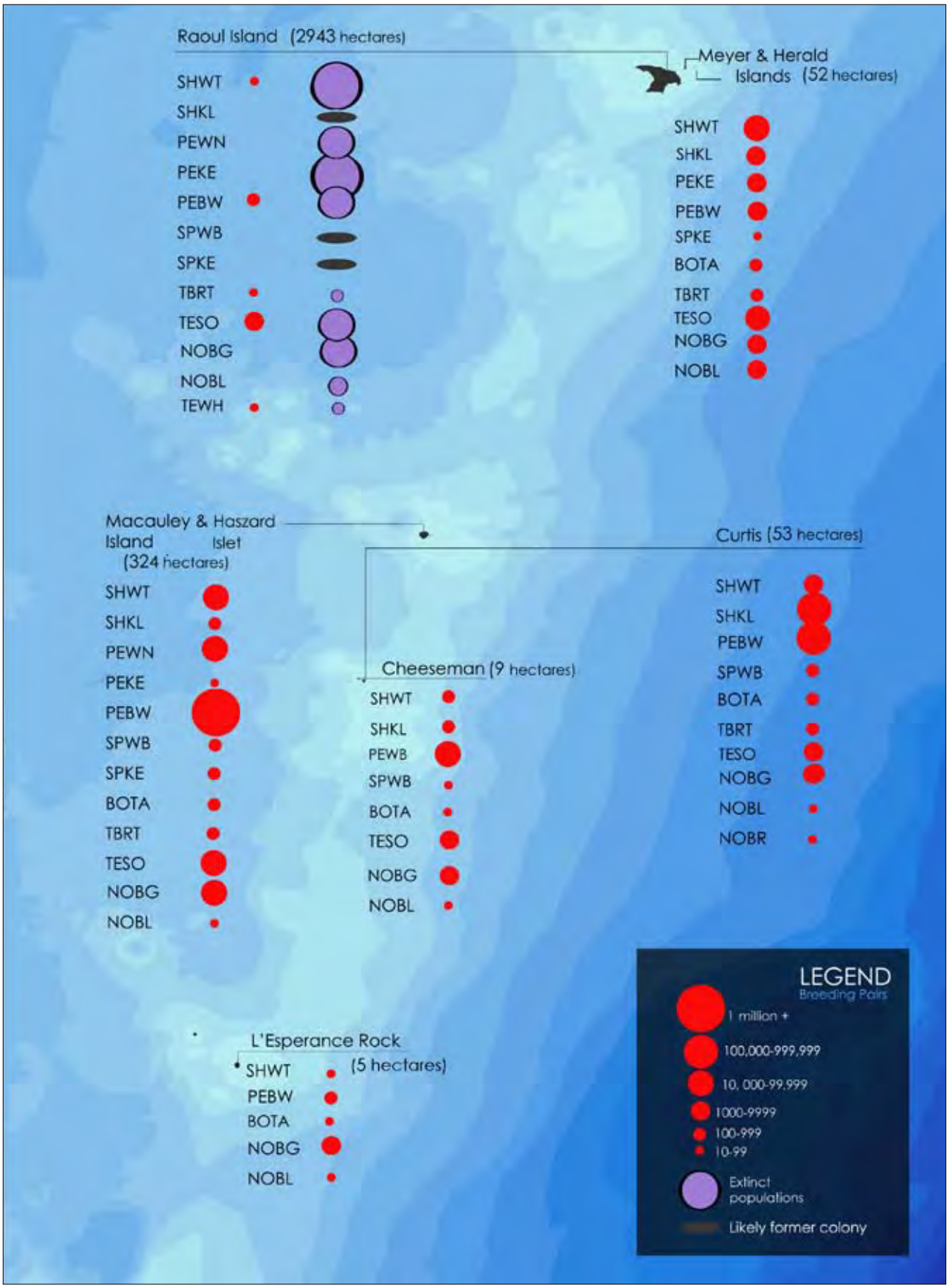

Figure 11. Estimated seabird populations for the Kermadec Islands, formerly (Raoul Island. where black ellipses denote possible historical breeding) and currently (all other islands and islets). See Table 1 for species codes; see also Appendix 3 (Sources: Taylor 2000a,b; Veitch et al. 2004; Ismar et al. 2010; CG, pers. obs.).

4. Seabirds of the Kermadec Islands

4.1 Seabirds of the Kermadecs, in general

In addition to the 14 seabird taxa confirmed breeding on the Kermadec Islands (see Table 1, Fig. 11), two additional species—the Phoenix petrel and Christmas Island shearwater—have been found ashore alive on Raoul and Curtis Islands, respectively (Murphy & Pennoyer 1952; Taylor & Tennyson 1994). A further species, the great frigatebird, has been reported in numbers (≤ 18 birds; DOC *Raoul Island Thirdly Reports*; K. Baird, DOC, pers. comm., 24 April 2008; CG, pers. obs., 2006, 2008) that suggest possible future breeding (G. Taylor, DOC, pers. comm., 9 June 2008). All three species are regarded as tropical (Spear et al. 2007). Of the 17 seabird taxa, three are endemic (OSNZ Checklist Committee 2010), with five ranked as Vulnerable on the IUCN *Red List of Threatened Species*™ (www.iucnredlist.org; viewed 27 March 2011) . Of further interest are two records of a diving petrel: the first was evidenced by a coracoid bone from archaeological investigations at Low Flat (Anderson 1980); the second is an historic observation by MacGillivray (1854) of a bird seen flying close to shore (Bourne & David 2008).

As many as 6 million seabirds breed at the Kermadec Islands annually, based on estimates made between 1967 and 2008 (Merton 1970; Tennyson et al. 1998; Taylor 2000a,b; Greene et al. 2004; Veitch et al. 2004; Ismar et al. 2010; CG, pers. obs., 2008; Appendix 3). Kermadec seabirds have four season-specific breeding cycles (Iredale 1913; Merton 1970; Veitch et al. 2004; G. Taylor, DOC, pers. comm., 1 April 2009) (see section 4.5.2 for more detail on seasonality):

- Summer–autumn: Kermadec, white-naped and black-winged petrels, wedge-tailed shearwater, and red-tailed tropicbird
- Autumn–winter: Kermadec petrel and white-bellied storm petrel
- Winter–spring: Kermadec little shearwater and Kermadec storm petrel
- Spring–summer: masked booby (Tasman booby), sooty tern, grey noddy (also known as grey ternlet), brown noddy (common noddy), black noddy (white-capped noddy) and white tern

Collectively, Kermadec seabirds use the full spectrum of nesting habitat: nesting above the ground in shrubs and trees, on the ground, and in burrows below the ground's surface (Fig. 12). Ground-nesting birds (masked boobies, red-tailed tropicbirds, grey noddies, Kermadec petrels, black and brown noddies, white and sooty terns, and probably white-bellied storm petrels) can be separated into those that nest in open ground and those that prefer shade, finding it under rock overhangs, on ledges with rock overhangs above them, under shrubs or within forest. Black-winged and white-naped petrels, wedge-tailed and Kermadec little shearwaters, and Kermadec storm petrels all nest in burrows. As a general rule, burrow size varies with bird size, ranging from a burrow with an entrance 50 cm wide and being over 3 m long (wedge-tailed shearwaters) to one whose opening is 5–8 cm wide and is less than 1 m long (Kermadec storm petrels).

In addition to, and sometimes instead of, using the Kermadec Islands and their waters for breeding, some seabirds spend time in the area on land or on water, or just pass through. Terns and noddies roost when not feeding, but many are pre-breeders—birds too young and inexperienced to nest successfully, many lacking nests or partners (as described of petrels; Warham 1996). In species other than those seabirds whose juvenile and immature stages are marked by distinctive plumages and bill colour (e.g. boobies, terns, gulls, albatrosses), it can be difficult to separate non-breeding from breeding birds in colonies, and almost impossible to do so at sea. This is worth bearing in mind when reviewing the data, as is the fact that birds feeding at sea are not necessarily breeding birds, nor are they necessarily associated with the nearest colony. For example, both the grey-faced petrel, which is known to breed in northern

Figure 12. Examples of nesting habitats: A. burrows in a steep-walled gully on Macauley Island (*photo: Mike Rosenberg, GNS*); B. former colony of sooty terns at Denham Bay, Raoul Island (*photo: Masterton, DOC Archive*); C. Mike Imber investigating a Kermadec storm petrel burrow on Haszard Islet, in which an incubating adult was found (*photo: Karen Baird, DOC*); D. Kermadec storm petrel burrow (*photo: Karen Baird, DOC*); E. red-tailed tropicbird on the nest, North Meyer Island (*photo: Chris Gaskin*); F. Kermadec petrel pair on the nest, North Meyer Island (*photo: Chris Gaskin*); G. black-winged petrel in a burrow (in dry forest), Raoul Island (*photo: Chris Gaskin*); H. burrows under trees on Macauley Island (*photo: Peter Dilks, DOC*); and I. grey noddies roosting at Hutchison Bluff, Raoul Island (*photo: Chris Gaskin*).

New Zealand, and Gould's petrel, which is known to breed on Cabbage Tree and Broughton Island, NSW, Australia (N. Carlile, pers. comm., 6 March 2010), can occur in the Kermadec region during their breeding seasons, either as breeding or non-breeding birds.

It is important to note that a number of seabird species breeding on the Kermadec Islands also breed on other islands in the Southwest Pacific. For example, wedge-tailed shearwaters also breed on Fiji, Tonga, Norfolk and Lord Howe Islands, eastern Australia, and New Caledonia (Marchant & Higgins 1990a); and black noddies and sooty terns also breed on Fiji, Tonga, Samoa and Norfolk Island (Higgins & Davies 1996). Thus, data from at-sea observations could include breeding and non-breeding birds from other populations.

To date, 42 seabird taxa have been recorded for the Kermadec region and seas north and northeast of the New Zealand mainland (Table 3).[2] Of these, only six are tropical seabirds; the remainder are southern-breeding seabirds. As indicated in Table 3, some are seabirds dispersing during their non-breeding periods and others are non-breeding seabirds from populations breeding elsewhere, including on islands close to the New Zealand mainland (e.g. grey-faced (MacLeod et al. 2008) and black (Bell et al. 2009) petrels). Some are seabirds on migration: mottled petrels (Jenkins 1979b; M. Imber, pers. comm., 1 May 2008) were recorded moving south through Kermadec waters during November, and sooty shearwaters were seen moving south through Kermadec waters en masse during late September to early November (Shaffer et al. 2006). The latter species, a migrant opportunist in tropical and subtropical waters, uses flock-feeding, scavenging and diurnal feeding on non-cephalopod invertebrates (in order of proportion of prey mass) (Spear et al. 2007). Recent tracking of sooty shearwaters from California to New Zealand in October 2008 (J. Adams, U.S. Geological Survey, pers. comm., 5 March 2009) showed that some of these birds spend some of their time foraging in Kermadec waters (Fig. 13).

Tropical seabirds from Pacific Islands to the north or from northern Australia have also been seen in the Kermadec area. For example, adult great frigatebirds have been observed along the Raoul Island coast and over the Meyer Islands and Herald Islets—in particular, in the Chanter Islands with their booby and tropicbird colonies (CG, pers. obs., 2006, 2008; DOC *Raoul Island Thirdly Reports*). Although frigatebirds feed mostly at sea, they are also kleptoparasites of other seabirds (notably boobies and noddies) (Harrison 1990), which is consistent with their presence over these particular islands.

Occurrence of southern storm petrels in Kermadec waters

While the migration of southern-breeding storm petrels towards the equator during the seasonal cooling of subtropical and tropical waters is known in both the western Pacific (Dutson 2001) and eastern Pacific (Imber 1984; Spear & Ainley 2007) Ocean, confirmation of 'wintering grounds' for the central south Pacific is sketchy in the extreme (Crossin 1974; Marchant & Higgins 1990a; Watling 2001; G. McCormack, pers. comm., 27 June 2007; J-C Thibault, Muséum National d'Histoire Naturelle (Paris), pers. comm., 14 March 2008). Lovegrove's (1978) sightings between New Zealand and Fiji in April and May 1977 are the only significant records for the region. In this context, the storm petrel sightings made during May 1982 and May 2007 that are discussed in the next paragraphs add substantially to our knowledge of the distribution of southern storm petrels in subtropical waters and the southwest Pacific Ocean.

C. Miskelly (DOC, pers. comm., 3 April 2009), during a trip to the Kermadec Islands in May 1982 that departed from Tutukaka (northern North Island), recorded five taxa of storm petrels (Fig. 14). The busiest day for sightings was 20 May, the day before the yacht *Derwent* reached Curtis Island, with black-bellied storm petrels (n = 9), white-bellied storm petrels (n = 4; seen only that day), a white-faced storm petrel and, possibly, a Kermadec storm petrel being recorded.

[2] In July 2011, three broad-billed prions and one fairy prion were found beach wrecked at Denham Bay (S. Potier, DOC, pers. comm., 30 July 2011). This was immediately following the very large wreck of prions on New Zealand's main islands' west coast beaches. The prions would be new records for the Kermadecs once confirmed (C. Miskelly, Museum of New Zealand Te Papa Tongarewa, pers. comm., 1 July 2011).

Table 3. Occurrence of seabirds from outside the Kermadec region that have been confirmed for the area 25°–35°S, 170°E–170°W (from Lovegrove 1978; Greene et al. 2004; Veitch et al. 2004; and unpublished observations from recent surveys by Imber, Gaskin, Baird, Potier and Shandley).

COMMON NAME	ZONATION*	OCCURRENCE (MONTHS)											
		J	F	M	A	M	J	J	A	S	O	N	D
Gibson's albatross	Sub	■	■	■	■	■	■	■	■	■	■	■	■
Antipodean albatross	Sub	■							■	■			
White-capped albatross	Sub							■			■	■	
Buller's albatross	Sub							■					
Black-browed albatross	Sub				■	■	■	■	■	■	■	■	■
Campbell albatross	Sub					■							
Black petrel	Te	■		■	■	■	■			■	■	■	■
White-chinned petrel	Sub							■					
Grey petrel	Sub						■	■	■			■	
Cape petrel	Sub						■	■	■	■	■	■	
Sooty shearwater/muttonbird/tītī	Sub, Te		■		■	■				■	■	■	■
Short-tailed shearwater	Te									■	■		
Buller's shearwater	Te				■	■					■	■	
Flesh-footed shearwater	Te					■				■	■	■	■
Christmas Island shearwater	Tr											■	
Giant petrel sp.	Sub, Te					■							
Broad-billed prion	Sub							■					
Thin-billed prion	Sub					■		■					
Antarctic prion	Sub							■					
Fairy prion	Sub, Te							■			■		
Blue petrel	Sub										■		
Grey-faced petrel	Te	■	■	■	■	■	■	■	■	■	■	■	■
Providence petrel								■					
Phoenix petrel	Tr			■		■							
White-headed petrel	Sub							■	■				
Soft-plumaged petrel	Sub	■		■	■		■	■				■	
Mottled petrel	Sub, Te											■	
Cook's petrel	Te	■			■	■					■	■	
Gould's petrel/New Caledonian petrel	ST/Tr	■			■	■							
Stejneger's Petrel	ST											■	
White-faced storm petrel	Te, Sub					■							
Black-bellied storm petrel	Sub					■							
Wilson's storm petrel	Ant					■							
Brown booby	Tr	■							■		■		
Black shag	Te											■	
Great frigatebird	Tr	■		■	■	■						■	
Subantarctic skua	Sub					■							
Arctic skua	Arc											■	
Southern black-backed gull	Te					■							
Red-billed gull	Te					■						■	
Little tern	Arc											■	
Crested tern	Tr				■								

* Tr = tropics; ST = subtropics; Te = temperate; Sub = subantarctic; Ant = Antarctic (islands); Arc = Arctic.

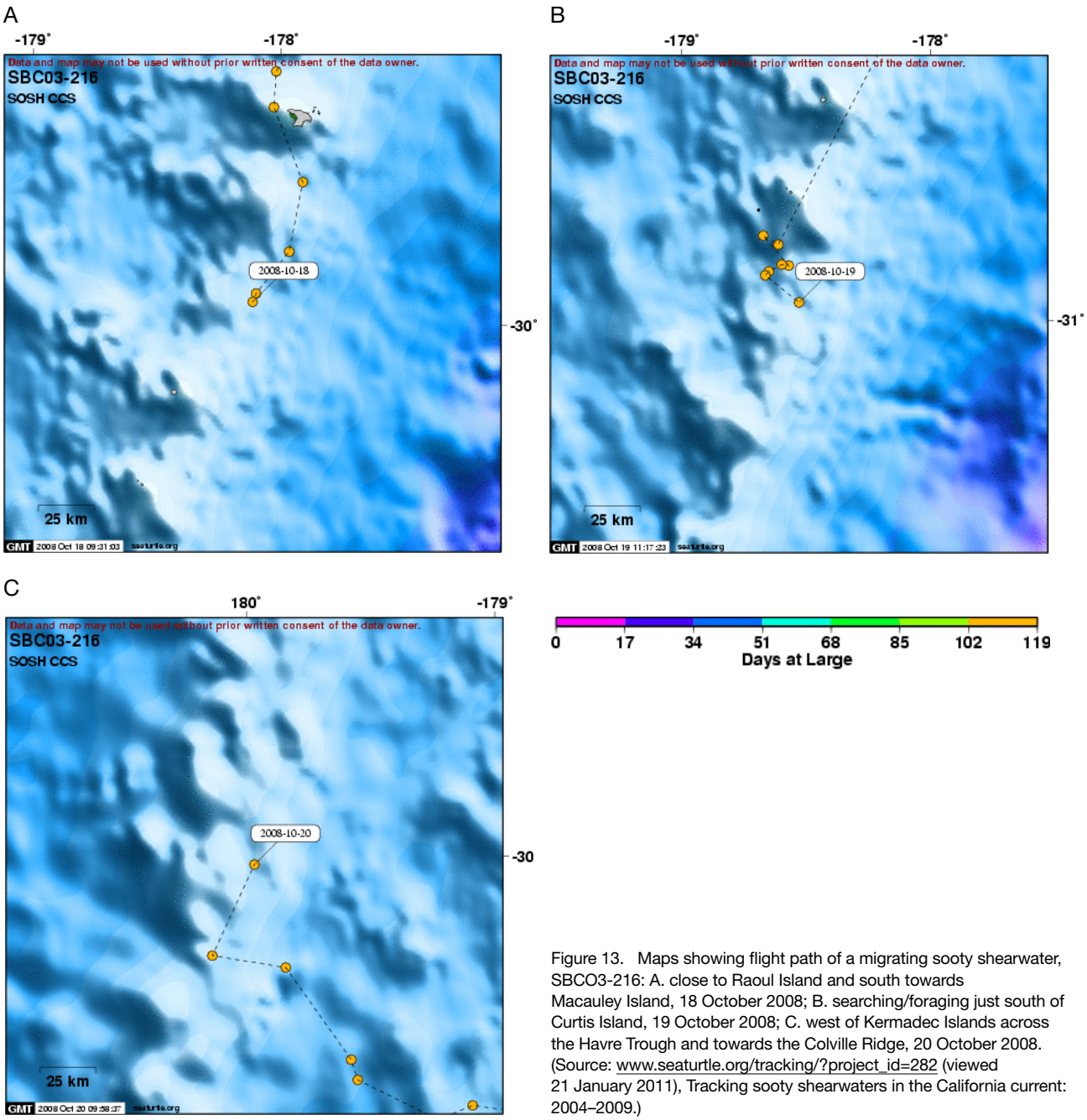

Figure 13. Maps showing flight path of a migrating sooty shearwater, SBCO3-216: A. close to Raoul Island and south towards Macauley Island, 18 October 2008; B. searching/foraging just south of Curtis Island, 19 October 2008; C. west of Kermadec Islands across the Havre Trough and towards the Colville Ridge, 20 October 2008. (Source: www.seaturtle.org/tracking/?project_id=282 (viewed 21 January 2011), Tracking sooty shearwaters in the California current: 2004–2009.)

One Wilson's storm petrel had been seen the previous day and a Kermadec storm petrel was definitely seen 1.5 km off Macauley Island. The black-bellied storm petrel was by far the most common storm petrel species observed during the trip, with 18 seen over 5 days. Earlier in the voyage (17 May), a white-faced storm petrel had also been seen west of the Poor Knights Islands.

During a return voyage to the Kermadec Islands from Wellington, aboard the RV *Tangaroa*, the author recorded the following observations on 4 May 2007, a day marked by the presence of storm petrels (see Appendix 4 for brief notes made during that trip). The first sighting occurred at 0720 h in glassy calm conditions, when a large (covering 2 km^2; n = 200+ birds), mixed feeding flock of almost exclusively storm petrels was seen at 32°7.2'S, 179°18.6'W—a location above the steep, western flanks of the Star of Bengal Bank (2750 m water depth) and c. 140 n.m. south-southwest of Macauley Island. The estimate of flock size is extremely conservative as birds were already around the vessel at the start of the day's watch. Also, obtaining accurate counts from both sides of the boat was difficult when identifying taxa. The storm petrel taxa identified were the Kermadec storm petrel, white-faced storm petrel, Wilson's storm petrel and

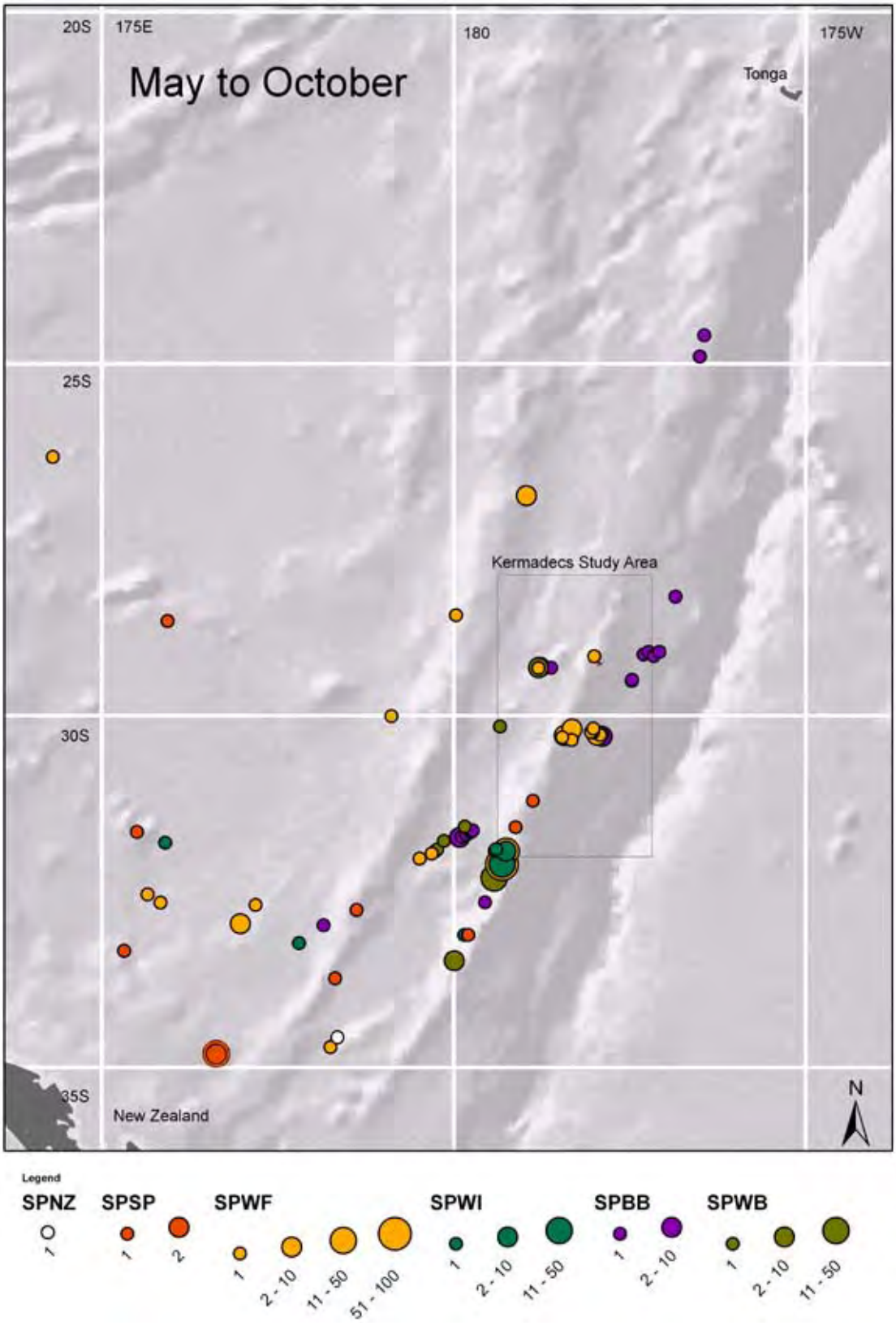

Figure 14. Storm petrel sightings in the vicinity of the Kermadec Islands from May to October, including May sightings from 1982 by C. Miskelly (pers. comm.) and 2007 by CG (pers. obs.). Species codes: SPNZ = NZ storm petrel; SPSP = unidentified storm petrel; SPBB = black-bellied storm petrel; SPWB = white-bellied storm petrel; SPWF = white-faced storm petrel (includes Kermadec storm petrel sightings); SPWI = Wilson's storm petrel. Storm petrel sightings close to the NZ main islands have not been included in this map.

white-bellied storm petrel. Black-bellied storm petrels may also have been among the group: birds of this species can be confused with white-bellied storm petrels when seen from a distance, and black-bellied storm petrels were seen later in the trip, both further north and in this area on the return voyage (18 May). Circling and foraging among the storm petrels were a few gadfly petrels: Kermadec petrels (n = 2), a black-winged petrel and a grey-faced petrel. *Physalia* sp. (Portuguese man o' war) was seen on the sea surface in this area. Later that day, more storm petrels (n = 10+) (white-faced and Wilson's storm petrels) were seen further north, at 31°56.4'S, 179°15'W, foraging and/or feeding along slick lines roughly parallel to our course. The next 5.3 h of cruising to reach a location immediately west of Havre and L'Esperance Rocks was in stark contrast to the earlier experience: only 65 seabirds (six species) were recorded (12.3 individual birds per hour) and only one further, unidentified storm petrel was seen. Single birds or groups of no more than four birds were seen, and none were observed feeding. The calm to light wind conditions (Beaufort = 1–2) throughout the day provided optimum viewing.

4.2 Seabirds of the Kermadecs, island-by-island

4.2.1 Raoul Island

On Raoul Island (Fig. 3), a small colony of **wedge-tailed shearwaters** exists on the cliff face and edge on the terrace close to the DOC base (Veitch et al. in press).[3] The birds' burrows have been excavated back into a single layer of soft tuff and all open onto a wide ledge of slightly harder rock. Formerly, vast numbers of burrows peppered the island, some of which were over 2.5 m long and had entrances large enough for a man to crawl into, according to Merton (1970). No **Kermadec little shearwaters** have been found breeding on Raoul Island, although individuals have been seen flying near the hostel and one was found in the guttering of the hostel in September 2007 (DOC staff notes; Veitch et al. in press). Burrow-nesting **white-naped petrels** once nested on the island's forested ridges and two birds were found (2005 and 2006) covered in the spiny burrs of a native grass (*Cenchrus calyculatus*) that prevented them from flying (E. Ward, DOC, pers. comm., 13 May 2008). This species is also known (from direct at-sea observations) to be in the waters around Raoul Island in May (CG, pers. obs.). Similarly, **Kermadec petrels** formerly nested mostly within forest, on the ground.[4] The one recent record of a Kermadec petrel for Raoul (at Nash Point, in September 2006) is of a bird nesting in grass (E. Ward, DOC, pers. comm., 13 May 2008). In 2008, **black-winged petrel** burrows were found in small, scattered colonies around most of the island, the birds favouring drier slopes and ridges up to c. 200 m a.s.l. (Ismar et al. 2010; Veitch et al. in press).[5] Of the storm petrels, individual **Kermadec storm petrels** flew onto the hostel veranda on two separate occasions (29 May 2008 and 24 August 2008), indicating that possible prospecting is occurring (DOC staff notes). They have been observed foraging close to Fishing Rock, the main landing for Raoul Island (K. Baird, DOC, pers. comm., 9 August 2007). **Red-tailed tropicbirds** nest on the cliffs at Hutchison Bluff, choosing sites on ledges and under overhanging rock. **Sooty terns** nest in the open on beach dunes and on debris slopes on Hutchison Bluff. **Grey noddies** are possibly breeding on the island; they certainly use Raoul Island cliffs at Hutchison Bluff and Boat Cove for roosting (Veitch et al. in press).[6] **White terns** nest in trees along the southeast coast (from Boat Cove to Sunshine Valley).

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[3] In 2011, a wedge-tailed shearwater was found on a nest at Nash Point, near Boat Cove (S. Potier and T. Shanley, DOC, pers. comm., 10 May 2011).

[4] In June 2011, two Kermadec petrel chicks were discovered at Wilson Point, near Boat Cove. Also, more chicks were seen on a rocky promontory separated from the main island. Up to 20 adult birds were seen flying in the vicinity (S. Potier and T. Shanley, DOC, pers. comm., 25 June 2011). In July, six birds were found under vegetation at nearby Nash Point; it was unclear whether these were adult birds or fledglings (no sign of eggs or downy chicks) (S. Potier and T. Shanley, DOC, pers. comm., 30 July 2011).

[5] Black-winged petrels continue to extend their breeding on Raoul Island, with new burrows detected during weeding operations above the Northern Terraces, near Boat Cove and at Denham Bay (S. Potier and T. Shanley, DOC, pers. comm., 10 May 2011).

[6] Grey noddy breeding has been confirmed for Hutchison Bluff (S. Potier and T. Shanley, DOC, pers. comm., 10 May 2011).

4.2.2 Meyer Islands and Herald Islet

Seabirds crowd the Meyer Islands and Herald Islets (Fig. 4), making the most of all suitable space and habitat. **Wedge-tailed** and **Kermadec little shearwaters**, and **Kermadec** and **black-winged petrels** occupy the upper, lightly forested slopes and summit area. However, not only were **wedge-tailed shearwaters** on the Meyer Islands found nesting under vegetation, they also have sometimes been found nesting in short burrows on rocky ground. **Kermadec little shearwaters** nest in shallow burrows on the Meyer Islands (K. Baird, DOC, pers. comm., 5 May 2007). **Kermadec petrels** nest in the open on the Meyer Islands (elsewhere in the Kermadecs, they seek shade under shrubs and trees). **Black-winged petrel** burrows can be found in a range of habitats: under grass, sedges, ice plant and fern; in areas of broken rock; and in forest. **Kermadec storm petrels** have been seen in the CMA close to the Meyer Islands, a possible breeding site. A dead storm petrel found in a burrow (but not collected) by a DOC worker on South Meyer Island in 2006 is believed to be of this taxon. **Masked boobies** nest on the Meyer and Herald landforms, on open ground with clear space for take-off and landing. **Red-tailed tropicbirds** nest along the tops of the cliffs, along with boobies and terns (see below). The red-tailed tropicbirds choose sites under overhanging rock (Fig. 12E) or vegetation. During the breeding season, non-breeding birds may be seen resting on the ground during the day, returning to the sea at night (Marchant & Higgins 1990b). In January 2006, a number of red-tailed tropicbirds were observed scattered across the water between Rayner Point and the Herald Islets (CG, pers. obs.), presumably bathing. On the Meyer Islands (April 2008), adults (and chicks) were found covered in dead ants and, while sitting on nests, their plumage had picked up dusty debris, all of which could be removed by bathing. **Grey noddies** nest on ledges on cliff faces and **sooty terns** nest in the open on debris slopes, whereas **black noddies** nest in a variety of trees and shrubs, preferring parapara; where there are no trees, black noddies nest on ledges on steep cliff faces. In January 2006, several **great frigatebirds** were observed over the Meyer Islands.

4.2.3 Macauley Island and Haszard Islet

The following observations are from the 1988, 1989 and 2002 expeditions to the Southern Kermadec Islands (G. Taylor, DOC, pers. comm., 5 March 2009; P. Scofield, Canterbury Museum, pers. comm., 5 March 2009). Macauley Island (Fig. 5) has a vast seabird population. Changes to the island's vegetation cover since the eradication of goats has had an impact on where seabirds are breeding. The recent eradication of Pacific rats is likely also to have an advantageous effect on seabird populations, especially those smaller seabirds that were formerly confined to cliff areas. **Wedge-tailed shearwater** colonies were situated on the slopes and plateau above the cliff tops around the edge of Macauley Island, and their burrows were also found on the mid–upper slopes of Mt Haszard and around the steep edges of the inland gullies. **Kermadec little shearwaters** were found on the cliffs, i.e. sites inaccessible to Pacific rats. Their burrows were also found on the debris slope at the back of Sandy Bay, but that slope—having been eroded away—no longer exists. On the water, they have been seen southeast of Macauley Island, during the breeding season, in loose or scattered groups of up to 20 birds, although most were often seen foraging in twos and threes (Fig. 14A). **White-naped petrels** nested in localised colonies, especially in Sandy Bay, on the slopes above Quadrat Gully, on the gully slopes and floor of Access Gully, on the plateau near Grand Canyon, in Jim's Gully, and on the upper slopes of Mt Haszard. Although their burrows were once found on forested ridges on Raoul Island, all colonies on Macauley Island are under grass, sedges or fern (G. Taylor, DOC, pers. comm., 5 March 2009). In 1988, **Kermadec petrels** were seen only high on the slopes around Mt Haszard, on the outer seaward side. However, in 2002, scattered nests of both summer- and winter-breeding birds were found along the northern coast from Mt Haszard to Sandy Bay; they were nesting in small numbers in the shade under shrubs and trees. **Black-winged petrels** were found from the shoreline to the highest point (i.e. wherever soil was present, doubtless related to their burrow-nesting habit), over 10 m from cliff-top edges, including edges of gullies. They were absent only from rocky cliffs and the shoreline. **White-bellied storm petrels** nest only on cliffs; a partially fledged dead chick found on the shoreline by a geological team in 2007 confirmed

this (S. Rosenburg, GNS, pers. comm., 15 May 2007). **Kermadec storm petrels** have been found nesting on Haszard Islet and are possibly also on the cliffs of Macauley Island. Both Kermadec and white-bellied storm petrels have been observed foraging during the breeding months close to Macauley Island. **Masked boobies** nest on Macauley and Haszard landforms, on open ground with clear space for take-off and landing, although some birds nest amid flattened *Cyperus*, with nest areas marked with white guano. On Macauley specifically, the birds were reported to be scattered all over the plateau, in areas of open *Microlaena* meadow, although now they probably nest at the edge of the island. Flocks of **masked boobies** have been seen roosting at night on headlands on Macauley Island. **Red-tailed tropicbirds** choose nest sites under overhanging rock or vegetation, seeking hollows around the tops of the sea cliffs and the slopes inland. **Grey noddies** were seen roosting and nesting only around the cliffs by the sea and a few inland cliff ledges such as on the side of Access Gully and at the back of beaches—all sites inaccessible to rats. **Sooty terns** nested in colonies inland, on the plateau slopes in areas of *Microlaena* meadow and near the summit of Mt Haszard, but now nests are likely to be restricted to cliff tops and coastal sites. **Black noddies** nested in colonies behind the beach on the eastern side, and in two gullies. In places where there are no trees, they nest on ledges on steep cliff faces. Birds have also been observed rafting in groups close to Macauley Island (CG, pers. obs.). Resting and preening birds gather during the day, as do birds that have been foraging far offshore, waiting for nightfall and the opportunity to return to their nests ashore (Warham 1996).

4.2.4 Curtis Island

Wedge-tailed shearwaters and their burrows were found on the mid-slopes of Curtis Island (Fig. 6), around the crater rim and eastern bay, under native iceplant or the sedge *Cyperus*, but only in deeper soil. **Kermadec little shearwaters** were abundant in patches, with the main colony on the western and southwestern slopes, under *Cyperus* and iceplant, generally on the upper slopes and plateau areas of the island. Some were also found on the main crater rim under iceplant. C. Miskelly found courting pairs of Kermadec little shearwaters in burrows and under sedges in May (Veitch et al. 2004), and Tennyson & Taylor (1990) found large chicks in burrows in October. **Black-winged petrel** burrows were found anywhere with soil that was not too hot or shallow. They were largely absent from the crater floors and rocky edges of the island. **White-bellied storm petrels** were caught in flight only (23 birds were caught by G. Taylor and A. Tennyson while spotlighting at night in September 1989); none were seen on the ground and there was no evidence of them in soil areas of iceplant and *Cyperus*. It is likely that they nest in rock crevices on cliffs and crater walls: a single downy chick was found by C. Miskelly in a rock crevice on Curtis Island (May 1982) c. 20 m a.s.l. (Veitch et al. 2004); and Tennyson & Taylor (1990), while unable to locate any nesting birds, did find an egg believed to be of this species in a cave—the species nests in rock crevices and under vegetation in locations away from the Kermadecs (Marchant & Higgins 1990a; Thibault & Varney 1991; J-C. Thibault, Muséum National d'Histoire Naturelle (Paris), pers. comm., 25 March 2009). **Kermadec storm petrels** have been observed foraging close to Curtis Island during the breeding months; however, none have been found to be breeding (G. Taylor, DOC, pers. comm., 5 March 2009). **Masked boobies** were scattered around the high points on the crater rim and flat plateau in iceplant areas, reflecting their preference for nesting on open ground with clear space for take-off and landing (although some birds nest amid *Cyperus*). Flocks were seen roosting at night on headlands on Curtis Island. The remains of one **red-tailed tropicbird** chick were found on a ridge on the island's southeast side in 1989 (G. Taylor, DOC, pers. comm., 5 March 2009). **Grey noddies** mostly nested around the rocky areas behind the beaches and in gullies, with nests also thinly scattered on the main crater walls. Unlike on Macauley, they were also present in areas of iceplant on the upper slopes of island but absent from dense patches of *Cyperus*. **Sooty terns** were most common on the crater floor and on the eastern slopes of the island. They also occurred in patches on open areas of bare ground on summit spurs and in gullies, but were absent from the main *Cyperus* areas. **Black noddies** were found mostly in gully floors, especially on the southeast side of the island. **Brown noddies** nested on the ground, on ledges and steep slopes, specifically, around the upper edge of the main crater rim and the southeast gully.

4.2.5 Cheeseman Island

The second, and last, recorded landing on Cheeseman Island (Fig. 7), in July 2002 (Greene et al. 2004), supplied the following data, unless indicated otherwise. It is likely that there were a few **wedge-tailed shearwaters** nesting in burrows around the edges of the vegetated plateau. However, **Kermadec little shearwaters** occupied most of the vegetated and central gully area of the island. Winter-breeding **Kermadec petrels** were present in very small numbers among the rocks in the lower part of the central gully (Kermadec petrels usually nest in the shade under shrubs and trees). **Black-winged petrels** probably occupied the central gully area in summer. **Masked boobies**, although not seen during the visit, were likely to be scattered across the upper part of the central gully. **Grey noddies** nest on the cliffs and ledges of this small island (P. Scofield, Canterbury Museum, pers. comm., 5 March 2009). Several corpses and eggs of **sooty terns** were found on the northern and upper western slopes of Cheeseman, suggesting the existence of a large colony.

4.2.6 L'Esperance Rock

Wedge-tailed shearwaters and **black-winged petrels** were found nesting in only a few pockets of soil on the upper central slopes and tops (Fig. 8). **Grey ternlets** were spread evenly over L'Esperance Rock, nesting and roosting on ledges of cliff faces everywhere above the storm wash zone. One **black noddy** was seen on the central high point (G. Taylor, DOC, pers. comm., 5 March 2009).

4.3 Diet and foraging strategies of Kermadec seabirds

Most seabird species take a wide variety of the invertebrates and fishes available in their foraging habitat (Gaston 2004). Although there have been no studies of the diet of Kermadec seabirds, results from detailed, extralimital studies of the same or related taxa elsewhere in the Pacific Ocean (Marchant & Higgins 1990a,b; Higgins & Davies 1996; Table 4) can suggest what seabirds might be feeding on and how they might be feeding when they are in the waters of the Kermadec region.

In terms of the fish component of the diet, flyingfish are common in Kermadec waters year round, although they are probably present in greater numbers and variety during the summer months, after having migrated south from the tropical seas during the seasonal warming of the southern Pacific Ocean. Small, mesopelagic fishes (and cephalopods and plankton) migrate toward the surface at night (descending during the day) and Spear et al. (2007) have shown that nocturnal feeding is an important foraging strategy for pelagic seabirds. Harrison's (1990) suggestion that vertical migrations have influenced the feeding habits of seabirds in Hawaiian waters may also apply to seabirds of the Kermadec Islands. Harrison's work also pointed to fish larvae in surface waters as important elements of seabird diets.

The cephalopod component of tropical seabird diets comprises not only flying squid (which share the distribution patterns of flyingfish, mentioned above), but also ommastrephid squids. These are surface-dwelling animals that are common and widespread in all warm oceans (Harrison 1990). The frequency with which seabirds (and tuna and dolphins) feed on juvenile squid implies that squid are a very important component of the subtropical marine ecosystem (Harrison 1990). Other cephalopods, which exhibit diurnal vertical migration (see above), also probably feature in the diet of Kermadec seabirds.

A significant component of the diet of grey noddies (Cheng & Harrison 1983; Harrison & Seki 1987), and white-bellied and white-faced storm petrels (Spear et al. 2007), is sea striders (*Halobates* spp.). *Halobates sericeus* has been recorded for the Kermadec region (Myers 1921), with 18 specimens collected from Denham Bay beach, Raoul Island, by Wallace and Oliver in

Table 4. Percentages, by number and mass (in parentheses), of fishes, cephalopods and non-cephalopod invertebrates in the diets of 14 seabird taxa studied in the eastern Pacific Ocean* and around Hawaii† and Australia/New Zealand/Antarctica‡. 'unk' = unknown percentage.

	FISHES	CEPHALOPODS	MISC. INVERTEBRATES
Large Procellariiformes			
Wedge-tailed shearwater*	39.1 (67.3)	60.5 (32.6)	0.4 (0.0)
White-naped petrel*	66.7 (83.9)	30.3 (16.0)	3.0 (1.0)
Kermadec petrel*	41.9 (47.7)	58.1 (52.3)	0.0 (0.0)
Wedge-tailed shearwater†	66.0	28.0	1.0
Small Procellariiformes			
Black-winged petrel*	85.7 (92.9)	13.6 (7.1)	0.7 (0.0)
White-bellied storm petrel*	53.6 (90.9)	26.8 (9.8)	19.6 (0.2)
Kermadec storm petrel (derived from white-faced storm petrel data)*	22.9 (93.6)	0.0 (0.0)	77.1 (6.4)
Kermadec little shearwater (derived from little shearwater data) ‡	unk	unk	unk
Pelecaniformes			
Masked booby*	93.1 (97.4)	4.9 (2.6)	2.1 (0.0)
Red-tailed tropicbird*	23.8 (40.4)	76.2 (59.6)	0.0 (0.0)
Masked booby†	97.0	3.0	0.0
Red-tailed tropicbird†	82.0	18.0	0.0
Laridae			
Sooty tern*	58.1 (59.5)	41.4 (40.5)	0.5 (0.0)
White tern*	62.7 (70.1)	8.5 (13.2)	28.8 (0.2)
Sooty tern†	46.0	53.0	Some shrimps
Brown noddy†	66.0	33.0	Some shrimps & marine insects
Black noddy†	92.0	7.0	1.0
Grey noddy (grey ternlet) †	61.0	11.5	18.0 crustacean 19.0 marine insect
White tern†	88.0	12.0	0.4

* After Spear et al. 2007.

† After Harrison et al. 1983.

‡ After Marchant & Higgins 1990a,b.

1908, and to the north and west of the island (Cheng 1976). Oceanic species of *Halobates*, in turn, have been found to feed on pelagic siphonophorans—like the Portuguese man-o'-war, the by-the-wind sailor, and the jellyfish *Porpita* sp. (Andersen & Polhemus 1976; Cheng 1985)—and on various planktonic crustaceans and fish larvae trapped in the surface film (Cheng 1974). They may also feed on floating fish eggs (Lee & Cheng 1974).

To obtain their prey, most Kermadec seabirds adopt more than one foraging strategy and feeding method, reflecting a degree of opportunism documented for other tropical and subtropical seabirds (Harrison 1990). However, in general, one strategy or method tends to be favoured by each taxon:

- **Associating with subsurface predators (being 'tuna birds')** is the predominant strategy for wedge-tailed shearwaters, Kermadec little shearwaters, masked boobies, sooty terns, brown and black noddies, and white terns (Jenkins 1979b; Harrison 1990; Spear et al. 2007; CG, pers. obs., 2006, 2007, 2008), with the birds commonly forming mixed flocks. Grey noddies, and white-naped and black-winged petrels can also sometimes be seen feeding in association with subsurface predators. Tuna, dolphin and pilot whale associations with seabirds have been observed in the waters around the Kermadec Islands, and it is

possible that the seabirds also associate with broadbill swordfish, mahimahi and other large predatory fish known to occur in the region (such as wahoo and kingfish), as they do elsewhere (Harrison 1990; Jaquemet et al. 2004). Associating with subsurface predators in tropical waters is the principal way for seabirds to access more prey (Jaquemet et al. 2004), and Ballance & Pitman (1999) stressed that feeding in multi-species flocks associated with subsurface predators is the most important feeding strategy of tropical seabirds.

- As mentioned above, **nocturnal feeding** is adopted by some species, and has been documented in white-naped, black-winged and Kermadec petrels, and in white-bellied and Kermadec storm petrels (= Kermadec white-faced storm petrel) extralimitally (Spear et al. 2007). Nocturnal petrels usually feed alone, but sometimes in the company of other seabirds (Harrison 1990).
- **Scavenging** is a strategy used by black-winged petrels and wedge-tailed shearwaters, allowing the birds to take advantage of cephalopods and other organisms that have died and floated to the surface (Spear et al. 2007).
- **Diurnal feeding on non-cephalopod invertebrates, and fish eggs and larvae** is common among Kermadec and white-bellied storm petrels, and grey and black noddies (G. Taylor, DOC, pers. comm., 1 April 2009; CG, pers. obs., 2006, 2007).
- **Chasing and catching flyingfish** in flight or just after they (the fish) land in the water has been reported for masked boobies (Heather & Robertson 1996; G. Taylor, DOC, pers. comm., 1 April 2009). Groups of immature boobies have been observed accompanying ships and chasing flyingfish flying from the bow wave (CG, pers. obs., 2007). A flyingfish regurgitated from a red-tailed tropicbird was collected on North Meyer Island in April 2008 (S. Ismar, University of Auckland, pers. comm., 1 July 2008).
- **Plunging and pursuing prey underwater** is virtually the only strategy used by red-tailed tropicbirds, which are among the most solitary of seabirds at sea and rarely feed among 'tuna birds'. This most pelagic of Pelecaniformes plunges from considerable heights (Harrison 1990). Masked boobies also plunge dive for prey, often with a cartwheeling-type action, but seldom from the heights of gannets.
- **Feeding in small flocks** is commonly seen in black-winged petrels, though seldom in-shore; such observations appear to confirm the very pelagic habit of the species.
- **Diving after their prey** is used by Kermadec, white-naped and black-winged petrels, and Kermadec little shearwaters, although the depths to which they dive are unknown. It is likely, however, that their diving capabilities are comparable to those recorded for Procellariiformes of similar sizes: mean depth = 2–15 m, maximum depth = 5–68 m (Mougin & Mougin 2000; Burger & Wilson 1988; Cherel et al. 2002; Shaffer et al. 2006; Rayner et al. 2008).

The above categories are consistent with the groupings of foraging strategies and of feeding methods established for tropical seabirds by Ballance & Pitman (1999), Spear et al. (2007) and Weimerskirch (2007). Kermadec seabirds can also be grouped with respect to foraging range (with some birds belonging to more than one group): birds that are pelagic and feed offshore (e.g. white-naped, Kermadec and black-winged petrels; wedge-tailed shearwaters; red-tailed tropicbirds; sooty terns; and, to a lesser extent, brown noddies and white terns)[7], and those that feed closer to islands (e.g. wedge-tailed and Kermadec little shearwaters; Kermadec and white-bellied storm petrels; masked boobies; brown and black noddies; grey noddies; and white terns). In terms of seabird foraging, it is the latter group that features within the Kermadec CMA and waters immediately adjacent (Fig. 14). Note, however, that most Kermadec seabirds have been observed feeding along the Kermadec Ridge, often within sight of islands. For example,

[7] Recent bird-borne tracking for black-winged petrels from Raoul Island indicates extensive foraging during breeding out over the Kermadec Trench, north, east and south of the islands and beyond, i.e. at the Subtropical Convergence 1500 km away (M. Rayner, NIWA/University of Auckland, 6 July 2011). This is the first tracking study for Kermadec seabirds and highlights the need for further research into seabird foraging across all species to better understand seabird ecology in the region.

both storm petrel taxa have been observed feeding approximately 150 n.m. from their colonies within a few days of the same species being seen foraging close to Macauley and Curtis Islands. Wedge-tailed shearwaters have also been observed among large mixed flocks short distances from islands and in flocks (feeding) well offshore, and white terns can be found well out to sea, although they can also be observed feeding just outside the surf line at Raoul Island. Likewise, grey noddies, which feed in massed flocks over the currents and eddies running between the Herald Islets, can also be seen in small flocks returning to islands from well offshore or mid-ocean (CG, pers. obs., 2007).

4.4 Seabirds in FMA10

While no direct correlations can be made between the fisheries and seabird data presented in this report, the distribution of fisheries effort targeting subsurface predators and that of at-sea observations of seabirds that feed in association with surface predators (e.g. wedge-tailed shearwater and sooty tern) suggests that foraging opportunities exist across large areas of ocean surrounding the Kermadec Islands.

The long-line fisheries data for FMA10 (Fisheries Management Area 10) for 2001–2007 (Fig. 15) show a concentration of fishing effort southwest and west of the Kermadec Islands, i.e. west of the Kermadec–Tonga Ridge, across the Havre Trough and over the Colville Ridge further to the west. There was also a concentration of effort to the north-northeast of Raoul Island in 2003. While the former may be the result of commercial expediency for smaller New Zealand-based vessels (i.e. fishing the waters closest to North Island ports yields a better cost–benefit ratio), catch data show that fish were caught across much of FMA10, with tuna species and swordfish dominating catches (B. Vander Lee, MFish, pers. comm., 15 July 2008; S. Baird, NIWA, pers. comm., 27 February 2009). The remainder of the effort extended towards the Kermadec–Tonga Trench and out into the South Fiji Basin. Areas to the west, north and east of FMA10 also receive some attention from the Taiwanese long-line fleet (Huang et al. 2008).

Jenkins (1979b) recorded two sets of observations in the same area of ocean: between 33°40.2'S, 176°37.8'E and 34°21'S, 176°12'E (10 January 1979: 26) and 34°4.8'S, 176°33'E (24 January). He observed four schools of 'tuna species with an American-style long-line vessel'—three seen on 10 January (1979b: 26) and one seen on 24 January (1979b: 34); common dolphins were among the fish on one occasion. The only birds in the vicinity were black-winged and grey-faced petrels, with no clear association between birds and the fish and dolphins. On 12 February of the previous year, Jenkins (1978: 157) observed wedge-tailed shearwaters 'in vast numbers spread out over the ocean and drifting generally in a northeasterly direction' at 29°34.2'S, 176°0.0'E (i.e. between northern New Zealand and Fiji). He stopped counting once he reached 2500 birds and commented that this was by far the largest group of wedge-tailed shearwaters he had seen away from the tropical Pacific Ocean (Jenkins 1979a). Four hours before the encounter (i.e. closer to New Zealand), he had seen a mixed, feeding flock of wedge-tailed shearwaters ($n = 50$) and sooty terns ($n = 12$). In mid-February, both wedge-tailed shearwaters and sooty terns have chicks at colonies on the Kermadec and Norfolk Islands (Marchant & Higgins 1990a; Higgins & Davies 1996) and the birds seen by Jenkins could have been from either colony or a mix of both (foraging to provision chicks), or could have been non-breeding birds.

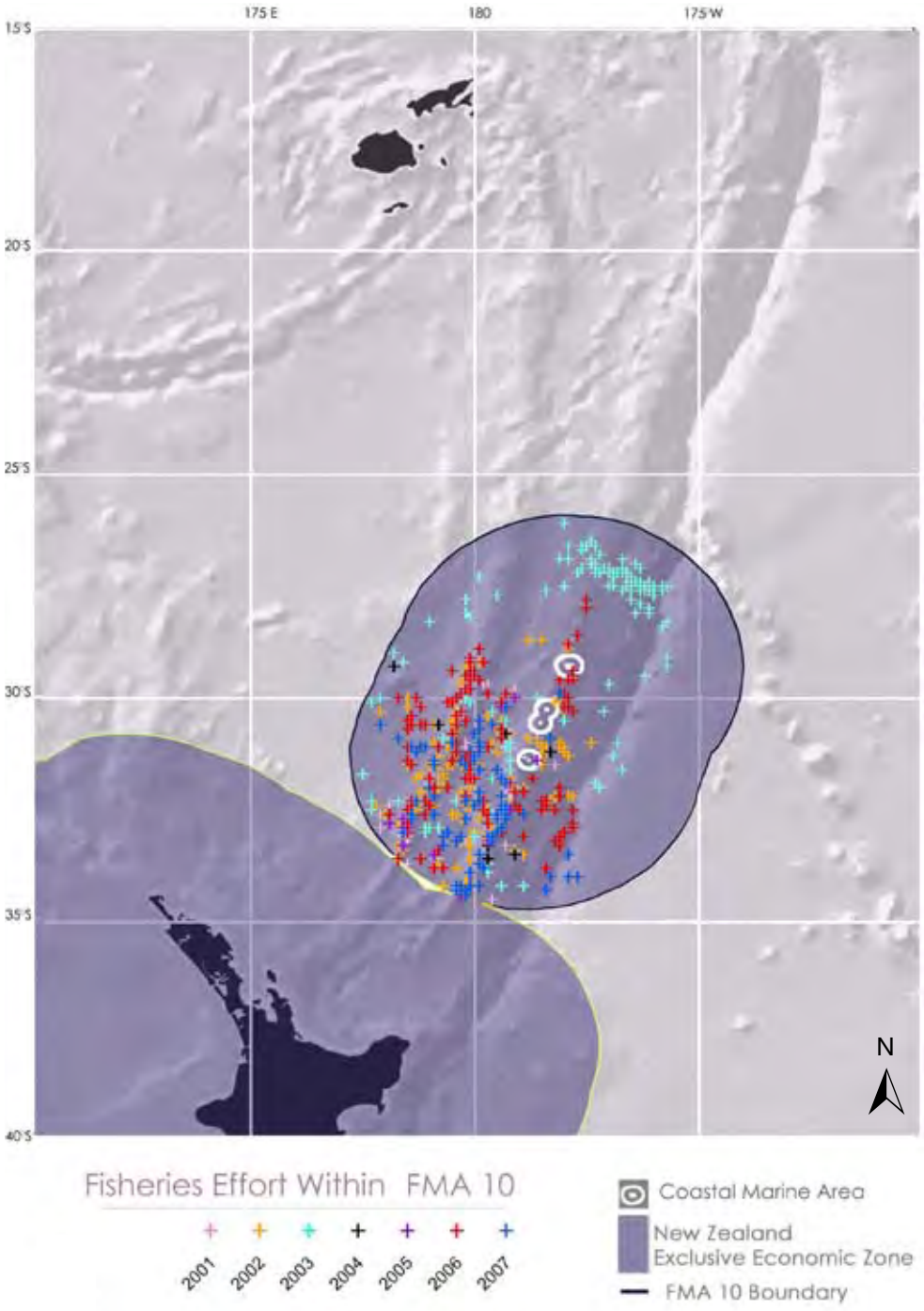

Figure 15. Distribution of long-line fisheries effort for FMA10 with set starts mapped October 2001–September 2007 (Source: Information Management Group, MFish.)

4.5 Factors influencing seabird use of the Kermadec Islands and their waters

Regulation of seabird populations can be governed by density-independent factors, such as climate, and density-dependent factors, such as the amount of food, predation and number of breeding sites available (Harrison 1990). The Kermadec Islands' isolation (approximately 1000 km from the New Zealand mainland and the nearest tropical islands) and subtropical location (29°–32°S) mean that tropical seabirds drawn to them are at their southernmost limits and subject to sea temperatures outside those defined as tropical (Ashmole 1971).

4.5.1 Wind, currents, bathymetry and ecosystem productivity

Wind data for November 1998 – July 2008 from the Raoul Island weather station (DOC base) appear to indicate a degree of stability, with mostly strong winds blowing from the southeast (between 110° and 130°) and occurring throughout the year (Fig. 16). Winds from the opposite quarter were overall less frequent, and were more likely to occur in June–November, to come from a greater range of directions (between 230° and 360°), and to not be as strong as those from the southeast. The evidence for an effect of wind on seabirds is equivocal. In their study of the foraging strategies of red-footed boobies in the Indian Ocean, Weimerskirch et al. (2005) concluded that boobies chose a heading unrelated to wind direction when leaving their colonies. The birds' network foraging pattern resulted in encounters with prey patches at various distances from the colony, the location of these patches being determined by environmental conditions, including surface mixing due to strong gales. How this relates to the Kermadec Islands and seabirds can be revealed only through future study, including bird-borne tracking of a range of species. However, persistent strong winds from one direction, through their consequential surface wind-stress and relatively small-scale linear divergences and convergences, may present a more predictable environment for seabirds searching large ocean areas for ephemeral and patchy resources.

Data from the Global Drifter Program indicate that currents are very variable around the Kermadec Islands, so that mean speeds are weak (c. 4 cm/s) and flows are mostly to the northeast.

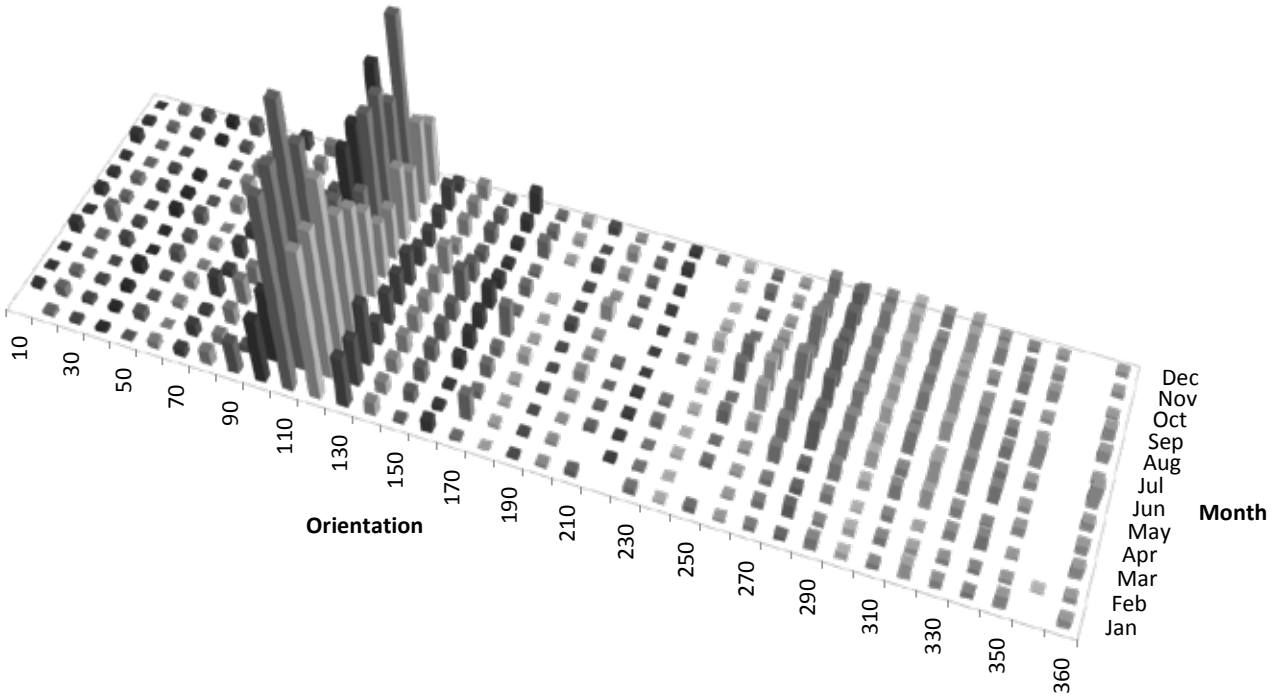

Figure 16. Average daily wind speed (accumulated) and direction at Raoul Island, November 1998–July 2008, plotted by month and bearing (orientation). (Source: http://cliflo.niwa.co.nz/; viewed 29 December 2009.)

However, the flows are primarily determined by eddy variability and speed (S. Chiswell, NIWA, pers. comm., 12 May 2009). Mapping of sea level anomalies in 2008 showed a persistent field of cyclonic and anticyclonic eddies propagating slowly westward through the region and across the foraging range of all Kermadec seabirds (Fig. 17). Localised surface currents are active, and the resultant, sometimes turbulent, patches are favoured by foraging flocks of noddies and terns, and by smaller numbers of shearwaters and storm petrels (Fig. 18). Boobies have also been observed feeding opportunistically in these areas. These currents can be found flowing:

- Through the gaps between neighbouring islands, islets and stacks (e.g. between Meyer Islands and Herald Islets; South Meyer and Raoul Islands; Macauley Island and Haszard Islet; and Curtis and Cheeseman Islands)
- Around large, isolated stacks, such as L'Esperance Rock, setting up long wake eddies
- Over semi-submerged rocks and reefs (e.g. Horn Rock, adjacent to L'Esperance Rock; MacDonald Rock, near Macauley Island; Parson's Rock, off Smith Bluff (Raoul Island); Dougall Rocks, off D'Arcy Point (Raoul); and Howard Rock, east of Lava Point (Raoul))
- Immediately offshore, out from headlands such as D'Arcy Point, Smith Bluff and Hutchison Bluff on Raoul Island

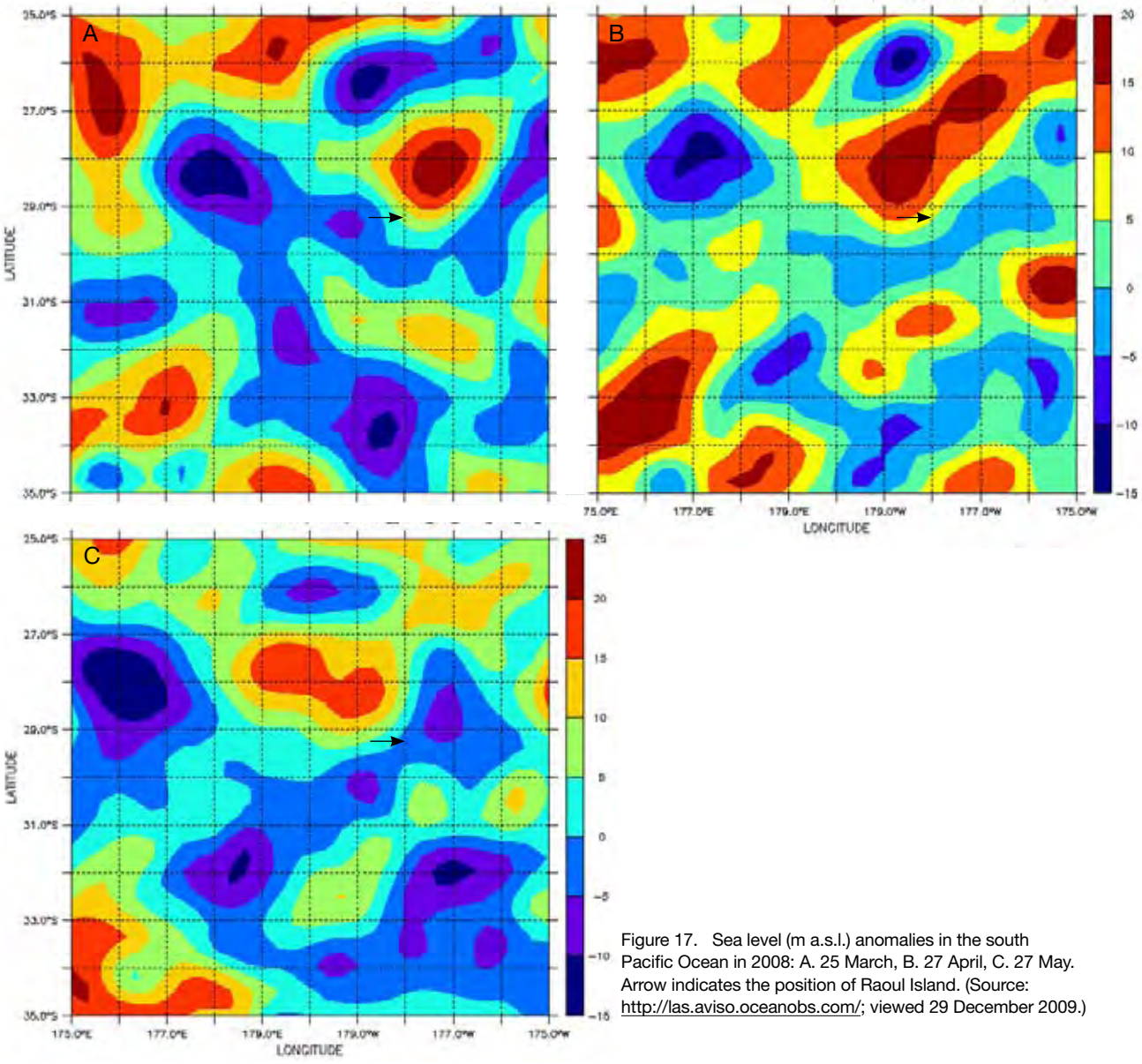

Figure 17. Sea level (m a.s.l.) anomalies in the south Pacific Ocean in 2008: A. 25 March, B. 27 April, C. 27 May. Arrow indicates the position of Raoul Island. (Source: http://las.aviso.oceanobs.com/; viewed 29 December 2009.)

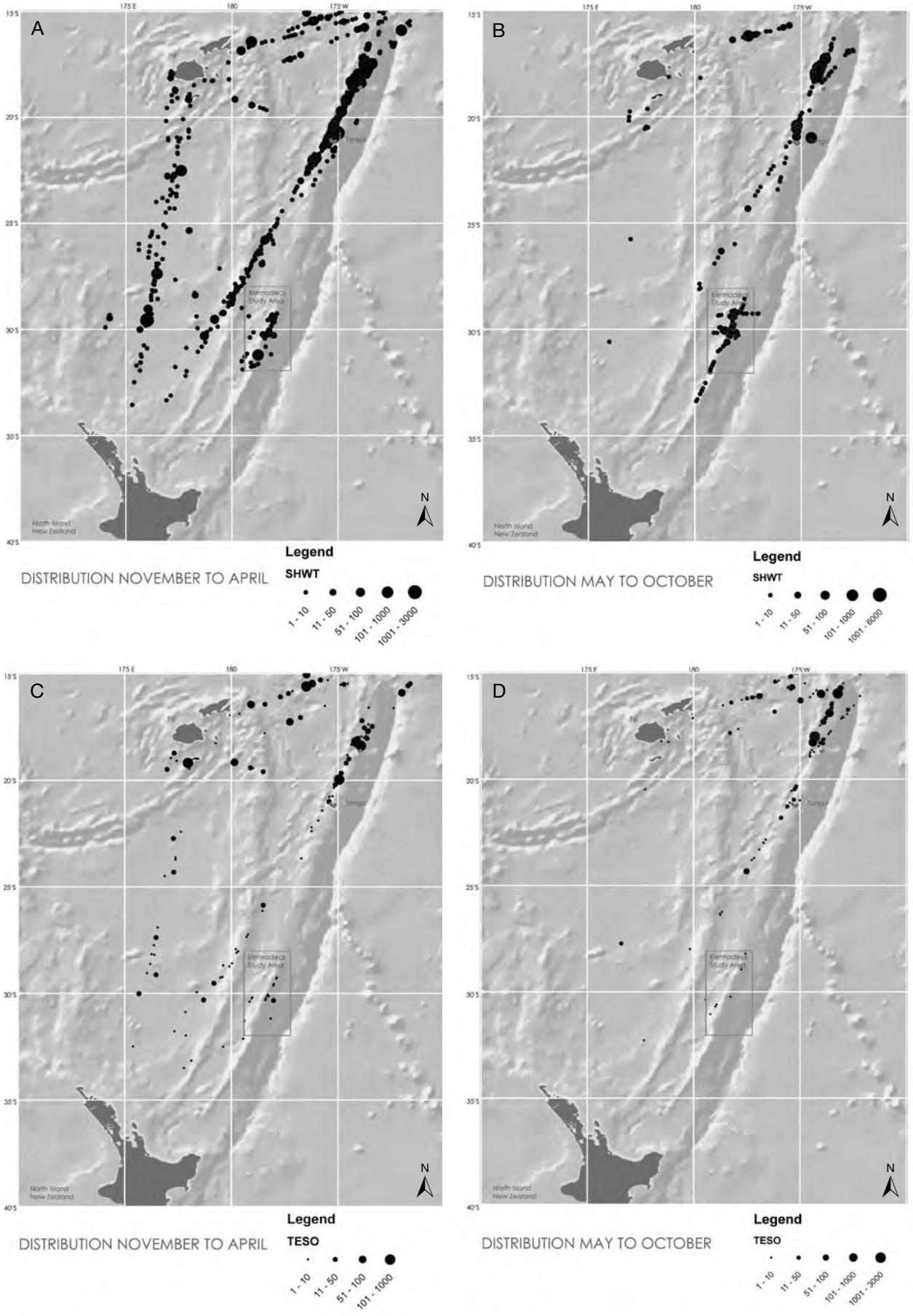

Figure 18. Distribution of wedge-tailed shearwaters, A. November–April and B. May–October (1970–2008); and sooty terns, C. November–April and D. May–October (1970–2008).

It is known that a wide range of seabird species exploit marine resources associated with seamounts (Thompson 2008), but that relationship is far from understood. This is particularly true for seabirds and the Kermadec Islands, with the latter being surrounded by a complex bathymetry—i.e. by seamounts and emergent islands, including those on the Kermadec–Tonga Ridge. From studies elsewhere, we know that physical processes and significant changes in bathymetry can concentrate marine organisms near the surface by direct transport or by inducing favourable conditions for their growth (White et al. 2007). This higher productivity, in turn, results in more baitfish (e.g. flyingfish and flying squid) locally, thus allowing larger populations of tuna and other predatory fish and marine mammals (Jaquemet et al. 2004; Weimerskirch et al. 2005). Daily migrations of predatory fish to and from the waters near islands and banks (such as has been documented by Johannes (1981) for skipjack and yellowfin tuna) bring these species within the foraging range of seabird colonies on isolated oceanic islands and enhance the seabirds' ability to provide adequate food for their young (E. Flint, U.S. Fish and Wildlife, pers. comm., 15 April 2009). Within the Kermadec region, local processes also serve to hold reef fish larvae close to the islands (M. Francis, NIWA, pers. comm., 22 May 2008), and within the foraging range of grey and black noddies and white terns in particular.

Tropical waters are characterised by low productivity relative to non-tropical systems, owing to their comparatively limited phytoplankton production (Ballance & Pitman 1999). However, it is possible that, as asserted for Hawaiian seabirds (Harrison 1990), the unique traits of the Kermadec Islands and their subtropical location give their waters characteristics that are intermediate between those of northern and tropical waters. Once again, extralimital studies can provide a guide in this respect. For example, a study of the influence of ocean productivity on the composition of seabird flocks associated with subsurface-predator schools in the eastern tropical Pacific Ocean found that booby flocks predominated in high-productivity waters, flocks of wedge-tailed shearwaters (Ballance et al. 1997) and Juan Fernandez petrels (formerly conspecific with white-naped petrels) occurred in intermediate-productivity waters, and flocks of sooty terns inhabited low-productivity waters in Hawaiian waters (Hebshi et al. 2008). As described above (sections 4.3 and 4.4), some of the at-sea observations of seabird foraging and feeding behaviour in the Kermadecs region appear to support these conclusions.

4.5.2 Seasonality

Seasonal variations in surface sea temperatures (SSTs) (Fig. 19) of Kermadec waters are clear, as is the biannual migration of warmer SSTs towards the South Pole in spring, and the equator in autumn (Fig. 20A–D). The influence of these patterns on Kermadec seabirds, however, is unclear at this time. Kermadec waters currently support large local populations of seabirds, with the largest numbers present during spring–summer and summer–autumn periods, bolstered principally by the huge black-winged petrel populations on the southern islands of the Kermadec group. Given that populations of summer-breeding Kermadec, black-winged and white-naped petrels, wedge-tailed shearwaters, and sooty terns on Raoul Island are now much smaller than previously (Veitch et al. 2004), seasonal seabird variation was probably once even more marked.

Kermadec petrels present an interesting case study. Records for the extirpated population on Raoul Island, estimated to have been 250 000 pairs (Iredale 1914) and probably the largest in the world (M. Imber, pers. comm., 1 May 2008), include those of eggs being found between 20 October and 6 December and records of all young gone by the end of May (Oliver 1955), confirming this species as a 'summer breeder' on Raoul (Imber 2005). Imber (2005) contrasted the former relative proportion of summer-breeding birds to winter-breeding birds (25:1) with that based on recent population estimates on the Herald Islets (0.03:1). On the Meyer Islands (where the population was estimated at 5000 pairs in 1967), eggs have been observed during November–June (Veitch & Harper 1998), with the laying predicted to peak after the end of January (Merton 1970). Elsewhere in the South Pacific, eggs of the Kermadec petrel have been collected during November–June (Brooke 1995; J-C. Thibault, Muséum National d'Histoire

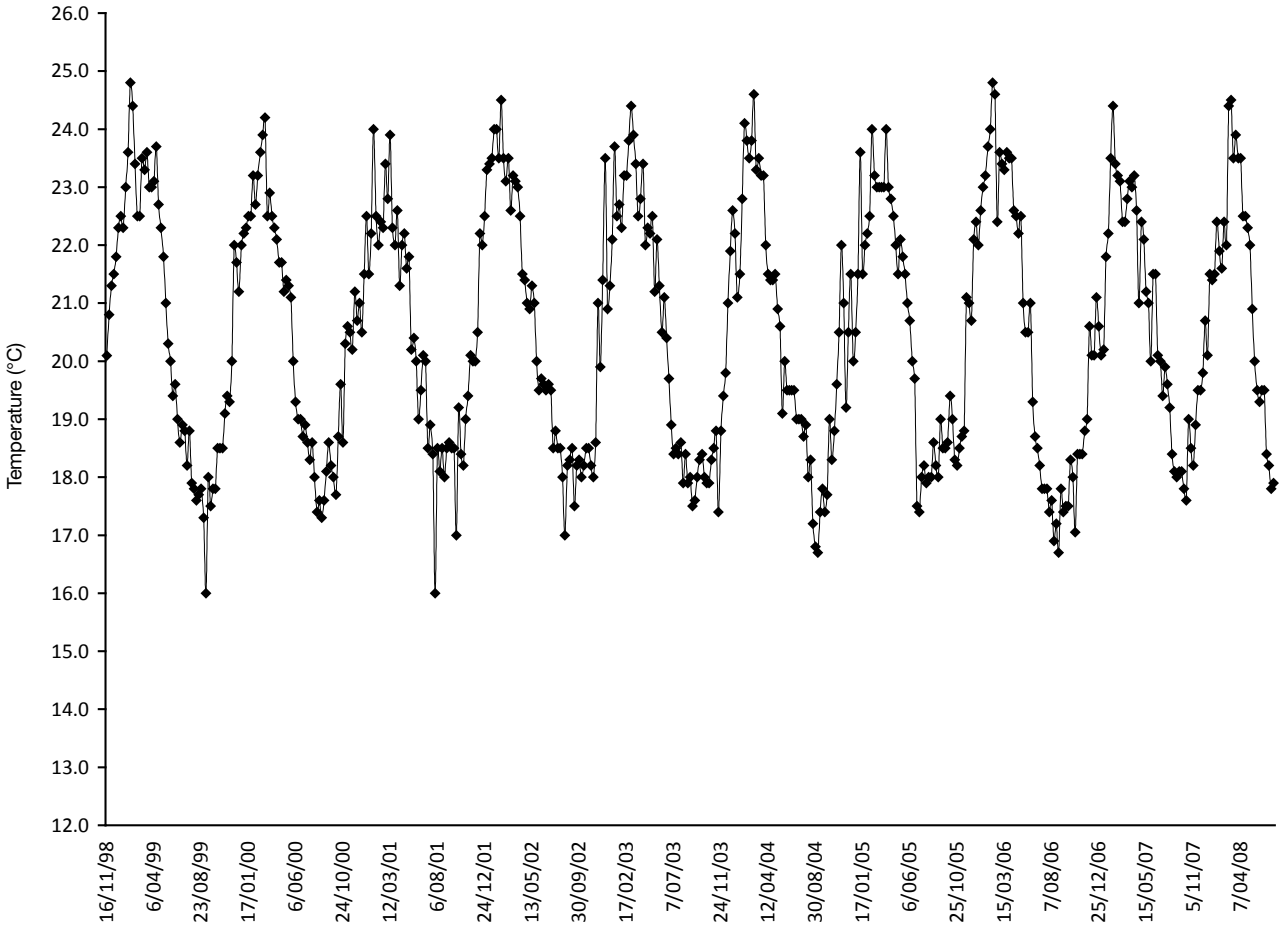

Figure 19. Sea surface temperature, recorded weekly, at Fishing Rock, Raoul Island, November 1998–July 2008. (Source: A. Shaw, NZ Metservice/DOC Raoul staff weekly readings.)

Naturelle, Paris, pers. comm., 20 May 2008) and Thibault considers the species to be an (austral) summer breeder with delayed egg laying in eastern Polynesia. That Kermadec petrels seem to be fundamentally summer breeders implies that the species has adapted to some seasonally abundant food supply in its favoured latitudes (M. Imber, pers. comm., 27 May 2008). Imber (2005) suggested that Oliver's (1955) idea of the two populations as distinct entities may prove to be correct.

4.5.3 Natural predators

The structure of intertidal and near-shore communities around seabird islands can be significantly altered by activities of guano-producing, colonially nesting seabirds, as a result of nutrient run-off into the marine environment (Bosman & Hockey 1986). The Kermadec Islands, with their pumiceous surface layers and soils, have no permanent streams, so run-off from the larger islands is likely to be confined to periods of heavy and sustained rain, or to areas immediately below cliff colonies or rocky-shore roosting sites. This is especially the case below steep land honeycombed with burrows (e.g. Macauley, Curtis and Meyer Islands) or cliffs where seabirds nest or roost on ledges (e.g. L'Esperance Rock, Cheeseman and Meyer Islands, and Haszard and Herald Islets) (K. Baird, DOC, pers. comm., 9 May 2008). The run-off, containing feathers, dead chicks and other nest debris, can be discharged directly into inshore waters from cliffs or indirectly through ravines and streambeds to the shore. Dead chicks and their remains may attract scavengers. In addition, fledglings (many usually retaining remnants of down) fly straight towards the open sea, often landing in the waters immediately adjacent to their colonies, and these birds—along with floundering and/or waterlogged birds—are likely to be taken by predatory fish such as sharks. To what extent this happens in Kermadec waters is unknown.

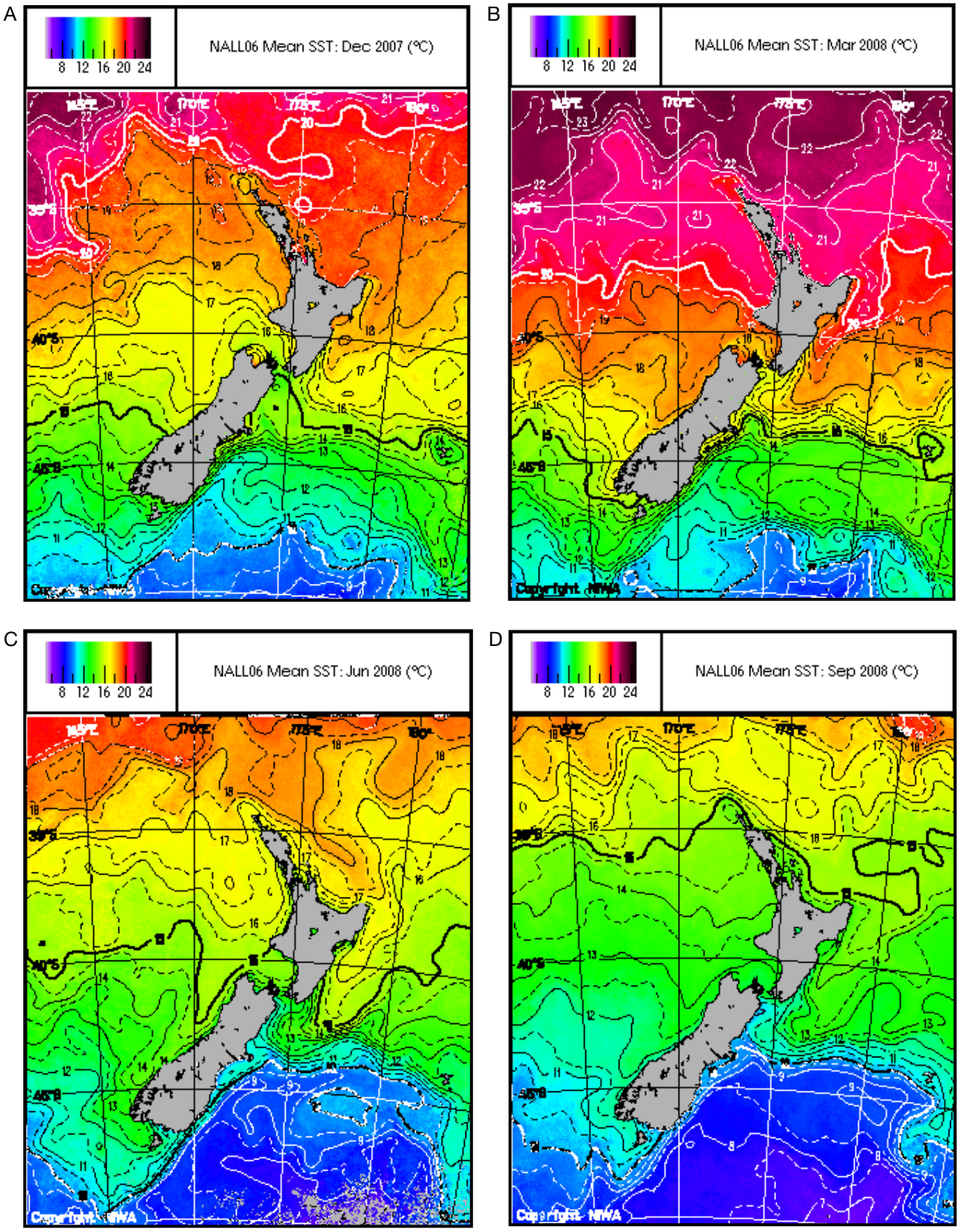

Figure 20. Seasonal migration of sea surface temperatures in New Zealand waters. Monthly means for A. December 2007, B. March 2008, C. June 2008, and D. September 2008. (Source: http://services.niwa.co.nz/services/sat/monthly; viewed 29 December 2009).

However, seabirds have been recorded in the diet of most species of pelagic shark, so it is likely that the Galapagos sharks at the Kermadec Islands take birds floundering at the surface. In addition, at the Poor Knights Islands, large snapper have been seen taking newly fledged birds (C. Duffy, DOC, pers. comm., 10 February 2009) and diving petrels (Thoresen 1969), so the large spotted black grouper found at the Kermadecs might also eat these (C. Duffy, DOC, pers. comm., 10 February 2009).

4.5.4 Human activities

New Zealand seabirds, including those in the Kermadec Islands, are exposed to a wide range of human activities within or adjacent to the Kermadecs CMA that could threaten them or their habitat, as outlined in Taylor (2000a).

On land

Seabirds are at greatest risk on land, within their colonies, with the most serious threats being posed by mammalian predators, disease and loss of nesting habitat. The eradication of predators and pests on Raoul and Macauley Islands has been costly; thus, managing biosecurity is paramount for the protection of seabirds, other fauna and the flora of these islands.

Introduction of mammalian predators The introduction of mammalian predators has the potential of extirpating Kermadec seabird populations, with the smallest seabirds (e.g. storm petrels, small shearwaters and noddies) being at greatest risk (see section 4.2.1 on Raoul Island, for example). The introduction of the Norway rat to the Kermadecs is generally attributed to the wreck of the five-masted, wooden schooner *Columbia River* in 1921. There have been a number of other shipwrecks at the Kermadec Islands (Ingram 2007), with all three since 1978 having been off Raoul Island: the *Picton* (1978) was dashed onto rocks off the southeast coast, the yacht *Shiner* (1984) was smashed on the rocks at Boat Cove when its anchor and stern lines gave way and the *Kinei Maru* 10, a Japanese long-line vessel, was run aground on Denham Bay in 1986. Through this period, Raoul Island remained infested with rats and it is not known whether any new rats or other predators came ashore from these shipwrecks. Now that the eradication of all mammalian predators from Raoul and Macauley Islands is complete, the populations of Kermadec seabirds can be said to be in a recovery state, although exactly what that means for individual species in terms of population size, and how they 'recover', is yet to be determined.

Unauthorised landings on islands Visitors who land on the Kermadec Islands without meeting biosecurity requirements place fauna and flora at risk. All of the islands are known Nature Reserves with restricted landings, but Raoul Island is the only island in the group with a permanent DOC staff presence—yet unauthorised landings have taken place there, most likely at Denham Bay and Boat Cove (DOC hut logbooks and *Raoul Island Thirdly Reports*). In addition to being possible sources of exotic, threatening organisms (e.g. fire ants, which have had a devastating impact on seabirds as well as other fauna and flora), unauthorised landings can be associated with an increased risk of fires (e.g. spreading from barbeques; see below for a discussion of fire risks) or vessels running aground (having been left unattended by crew going ashore). In a recent example (in 2007), a solo French yachtsman swam ashore at Denham Bay, leaving his vessel unattended. Should this become a significant risk on Raoul, a remote surveillance camera (or cameras) could be installed at Denham Bay and Boat Cove and monitored from the DOC base, similar to the system installed at Cape Rodney–Okakari Marine Reserve at Leigh/Goat Island (K. Baird, DOC, pers. comm., 9 February 2009).

Disease Arrival of avian disease on isolated islands can have devastating consequences for island populations, as seen by the impacts that the introduction of avian malaria and avian pox had on Hawaiian birds (Van Riper et al. 1986) and saddlebacks on Long Island in the Marlborough Sounds (Hale 2008). Diseases of birds could potentially be transmitted via equipment that has been used on birds elsewhere. The risk of people arriving on Raoul Island

carrying disease that could infect wild bird populations has not been specifically assessed. However, disease risk through contact with people is generally considered to be low, as the mechanism of transfer is oral (Jackson et al. 2000). Adherence to strict biosecurity controls is essential for anyone working directly with seabirds, to reduce the risk of spreading disease. As populations of seabirds diversify and expand, disease risk should be analysed, as there will be increased contact between birds and humans (such as when seabirds fly into lights at the hostel). This risk could increase further if injured birds were cared for and re-released into the wild (K. Baird, pers. comm., 25 March 2010).

Fire Any fire has the potential to kill Kermadec seabirds directly, as well as to severely damage their habitat. The Kermadec Islands can experience long dry periods and the vegetation can become tinder dry. Although no fires have been documented for the Kermadec Islands, fires on these remote islands could be devastating, especially if they occur during the breeding season, as all seabirds are vulnerable at that time, although to varying degrees. For example, for surface-nesting seabirds, their nests could be destroyed and chicks killed, while burrow-nesting seabirds could lose adults as well as nests and chicks; tree-nesting seabirds (e.g. white terns and black noddies) could lose adults, nests, chicks and nest sites if fire swept through their preferred habitat. The very worst time for a fire to occur is during the incubation period. Non-breeding seabirds could also be affected if a fire occurred at night when birds were on the ground. Nocturnal seabirds (e.g. petrels) are at particular risk because, attracted by the light of a night-time fire, they could fly into the fire (ship-wrecked sailors used this method to catch seabirds in the past; Warham 1996). Both Macauley and Curtis Islands are densely covered with sedges and grass that would burn extensively in summer. On Raoul Island, activity associated with the DOC base could increase the risk of fire there, although with staff on permanent stand-by, any fires in the vicinity of the base would theoretically be detected early and be fought at relatively short notice. Fires breaking out in remote parts of the island and on other islands in the group, however, are unlikely to be put out by human intervention. Current DOC policy on Raoul Island prohibits the use of open fires by staff, except in the concrete barbeque. Scientific parties visiting other islands should be prohibited from using open fires for cooking and allowed to use only cooking stoves. Fires lit by unauthorised visitors pose a potential risk, although there is no evidence that this has ever occurred (K. Baird, pers. comm., 25 March 2010).

Human disturbance Disturbance can result in the death of eggs, chicks and adults; in the abandonment of nests; and in burrow collapse through trampling, especially on densely populated islands such as the Meyer, Macauley, Curtis and Cheeseman Islands (on these islands, visits are restricted to monitoring and research purposes only). All visits should be limited to, or at least led by, experienced DOC staff/researchers, and training should be mandatory for all members of all parties (e.g. on Raoul and the Meyer Islands, this includes weed teams and researchers). Human disturbance is of particular concern for Raoul Island, as it is the only island in the group where visitors are allowed ashore (see Ecotourism, below). Time of the year must be a major consideration, as keeping visit impact to a minimum is essential.

Ecotourism The potential threats posed by ecotourism to seabirds of the Kermadec Islands are similar to the impacts of other human activities presented in this section: possible introduction of mammalian predators and disease, fire, human disturbance, and pollution. At present, the potential risks arising from ecotourism are relevant only to Raoul Island, which (as mentioned above) is the only island where visitors are allowed ashore, and then only by permit issued through the DOC Warkworth/Great Barrier Island Area Office, Warkworth. Customs clearance is also required as part of the permit process. Landings are permitted at just three places—Fishing Rock, Boat Cove and Denham Bay—although conditions can mean that reaching any of these sites is impossible. In general, overnight stays are not permitted on Raoul Island. Ecotourism opportunities at the Kermadec Islands are limited by the islands' remoteness; they are away from main cruise ship routes—there has been only one visit per year between 2006 and 2009. The islands are, however, a regular stopover for small vessels, in particular yachts, sailing between

New Zealand and the Pacific Islands. Live-aboard or boat-based operations for diving, sightseeing and bird-watching, are the most suitable ecotourism option for visiting the Kermadec Islands.

DOC operations at Raoul Island Raoul Island is the only island in the group with any permanent habitation and tall structures (i.e. radio aerials, flying fox and a flagpole). While there has been no reported seabird mortality associated with these structures, any proposal to develop further infrastructure on the island, particularly wind turbines, should take the potential adverse impacts on seabirds into consideration. Data that should be collected prior to approval of any new structure include the species using the site, and the number of bird movements through it by day and night over a full annual cycle (R. Powlesland, pers. comm.). Collision fatalities during and post-construction should also be monitored. Powlesland (2009) identified the main factors contributing to bird fatalities arising from collisions with turbines as proximity to areas of high bird density or high frequency of movements; bird species (some are more prone to collision or displacement than others); landscape features that concentrate bird movement; and poor weather. Light pollution can also present a risk to some sea bird populations breeding near human habitation. Seabirds are occasionally attracted to the lights of the Raoul base (e.g. two Kermadec storm petrels and one Kermadec little shearwater in 2008; Raoul Island Thirdly Reports, DOC); however, there is no evidence that the base's lights represent a risk to these species. Bird strike is a risk during helicopter operations on any of those islands where large numbers of seabirds are diurnally active above the colonies (e.g. black-winged petrels, masked boobies, red-tailed tropicbirds and sooty terns).

Pollution Several pollutants can directly impact on seabirds or enter the marine environment from land around the main islands of New Zealand, but none pose a significant problem at the Kermadec Islands. Rather, relatively small-scale operations, such as the handling of fuel, chemicals, paints and rubbish at the DOC base on Raoul Island, could have direct impacts on seabirds. Provided strict protocols for handling are maintained, these impacts are likely to be negligible. Only one fuel depot exists in the Kermadec Islands, on L'Esperance Rock, principally to provide fuel for an emergency evacuation of DOC personnel by helicopter from the Raoul Island base. However, fuel is periodically drawn from the depot for helicopter runs to Raoul Island for conservation operations. Re-supply of the depot is usually undertaken by New Zealand Defence Force helicopters. Empty fuel drums must be uplifted and the depot checked to ensure that there is no corrosion of the drums or spillage of aviation fuel. If any spillage, contamination or corrosion of drums is discovered, appropriate clean-up or mitigation should be required as soon as practically feasible to prevent any impacts to the natural ecosystems (K. Baird, pers. comm., 25 March 2010).

Commercial and cultural harvesting Archaeological (Anderson 1980) and historical (Large 1888; Iredale 1910; Oliver 1930) records show that seabirds were harvested on Raoul Island during historical times in very large numbers. Exactly who the Polynesian or Māori inhabitants were during that period has been the subject of much speculation among 19th and early-20th century ethnographers, and more recently by archaeologists (Anderson 1980; Johnson 1995). The exploitation of seabirds on Raoul Island by European whalers, settlers and visitors in the 19th and early-20th centuries presents a much clearer picture (Oliver 1910). Petrel and shearwater chicks, particularly those of surface-nesting Kermadec petrels, were harvested each autumn by settlers, the carcasses smoked and then preserved for consumption throughout the following year (Large 1888; Oliver 1910; Bacon 1957). Eggs from sooty terns and red-tailed tropicbirds were also harvested (Bell 1911). No commercial or cultural harvesting of seabirds currently takes place at the Kermadec Islands. Any future consideration to harvest seabirds will need to address a number of conservation issues, including who has the right to harvest seabirds at the Kermadecs.

Marine-based activities within the Kermadec CMA

Although threats on land pose the greatest risk to seabirds and seabird populations (as above), marine-based activities can impact on the seabirds using the Kermadec Islands CMA.

Oil spills and oil-related threats Any accidental collision or shipwreck could result in the release of fuel oil or cargo oil into the sea. Therefore, although there is a relatively small number of vessels currently operating in the area, vessels are required to exercise great care both close to the islands and in the vicinity of the marine reserve (www.maritimenz.govt.nz/Environmental/Legislation-regulations-conventions.asp (viewed 23 August 2011); DOC 2011).

Plastics/marine debris Seabirds often investigate floating debris at sea while foraging (CG, pers. obs.) and it is possible that some pick up plastic pieces, which, in turn, could be fed to chicks (Spear et al. 1995). To date, there is no evidence of Kermadec Island seabirds doing this, although pelagic species of petrels and albatrosses are known to ingest plastic extralimitally (e.g. the Laysan albatross on Midway Island). The shores of Raoul Island are littered with marine debris, including large amounts of plastic material, most likely originating from ships. Coconuts and a North Island real estate sign on the shores (K. Baird, DOC, pers. comm., 9 February 2009) also suggest that some of this debris comes from much further afield. The amount of debris present on the shore suggests that ingestion of plastic debris is a significant potential threat to seabird populations. Debris on the shore could also later be washed out to sea, once again posing a threat to seabirds. As seabird populations on Raoul Island increase, the incidence of this threat will need to be investigated. Removal of plastic debris washed up on Raoul Island on a regular basis should be considered. Stockpiling it away from the shore where it can no longer re-enter the marine environment could be undertaken as an interim measure (K. Baird, pers. comm., 25 March 2010).

Vessels within the CMA Seabirds may strike superstructure, rigging, masts, antennae and cables of brightly lit vessels close to the islands of the Kermadecs. This can result in injury (note that broken wings result in the death of seabirds, because they are unable to fly and feed) or outright death (R. Powlesland, DOC, pers. comm., 16 February 2009). Storm petrels, black-winged, Kermadec and white-naped petrels, and Kermadec little and wedge-tailed shearwaters are attracted to bright deck lights. Some birds land on vessels and hide themselves on board in various places: under winches, life rafts and containers; among piled chains; in inflatable boats and gear lockers; even entering passageways inside vessels (CG, pers. obs., 2007). Birds can get trapped and not be discovered for days and/or they can get coated in oil residues and grease. Ships anchoring near the Kermadec Islands at night, particularly near the Herald group, should be required to keep deck lights to a minimum and the use of floodlights should be prohibited. Downward-pointing deck lights, operating at low light levels, are best (K. Baird, DOC, pers. comm., 25 March 2010). All birds found on vessels should be released unharmed, preferably at night and in low-lit areas, to minimise the likelihood of their return to the vessel. Weakened or distressed birds released during daytime hours could be harassed or preyed upon by other birds.

Fisheries interactions As the Kermadec Marine Reserve is a no-take reserve under the Marine Reserves Act 1971, no commercial or recreation fishing is permitted within the CMA. However, any illegal fishing in the CMA carries the risk of incidental capture (see below).

Marine-based activities in areas adjacent to the Kermadec CMA

Oil spills As mentioned above, oil affects seabirds directly, with discharges of waste engine oil being a regular contributor to the problem globally.

Incidental capture of seabirds during fisheries operations Recent incidents of high albatross bycatch in New Zealand waters, including the capture of 54 albatrosses in November 2006, prompted the New Zealand Government to strengthen regulations on seabird bycatch mitigation (Black 2008). According to data collected from 1990 onwards (Table 5, Fig. 21), seabird bycatch within FMA10 was a significant issue in 2003 and 2004, and even more so in 2006. In 2003, Philippine vessels caught mainly grey-faced petrels (10 birds out of 13) (Waugh et al. 2008), and in 2006, the bycatch was mainly albatrosses (54 birds out of 63) (Rowe 2009). All birds captured were southern breeding seabirds, i.e. no Kermadec-breeding seabirds were reported captured during long-lining within the FMA10 during 1990–2008. Historically, observer coverage in this fishery has been sporadic and at an inadequate level to accurately estimate seabird bycatch (Black 2008). However, coverage has increased in recent years (18% of sets observed during the 2007/08 observer year), as one of the regulations requires surface long-line vessels to notify MFish of their intention to fish using the surface long-lining method. Unfortunately, logistical and resourcing difficulties with placing observers in this fishery remain (S. Rowe, pers. comm., 2 March 2009). The several species of shearwater and smaller petrels found in the tropical latitudes of the Pacific Ocean are considered likely to be susceptible to incidental capture (Watling 2002), even though seabird bycatch rates are believed to be lower in tropical long-line fisheries than similar fisheries in high latitudes (Black 2008; Huang et al. 2008). However, given the large long-line effort across tropical waters, even low bycatch rates have the potential to impact on seabird populations (Black 2008), including Kermadec seabirds migrating towards the equator post-breeding. A recent study of Taiwanese long-line fisheries (Huang et al. 2008) found that seabirds were caught to the east of the Kermadec region, and outside New Zealand's EEZ. Huang et al. (2008) stressed the need for further analysis of the characteristics of fishing activities and seabird ecology, to obtain more information for seabird bycatch estimation and reduce seabird incidental catch. A broader ecological approach is critical because, although estimating bycatch is an important part of fisheries management, it does not actually solve the issue of bycatch (S. Rowe, DOC, pers. comm., 2 March 2009). The focus for DOC, working with MFish and the fishing industry, should be to gather information on fishing practices that lead to bycatch events and then to find ways to mitigate the problems.

Table 5. Seabird species and numbers of observed seabird captures in the surface long-line fishery within FMA10 for 2003, 2004 and 2006. No seabirds were observed caught in any of the other years during 1990–2008. (Compiled from Baird 2001, 2004a,b,c, 2005; Manly et al. 2002; Baird & Smith 2007; Waugh et al. 2008; Rowe 2009.)

COMMON NAME	2003	2004	2006	TOTAL
Albatross, unidentified			36	36
Wandering albatross			18	18
Grey-faced petrel	10		1	11
Black-browed albatross			2	2
Grey petrel			2	2
White-chinned petrel			2	2
White-headed petrel	2			2
Petrel, unidentified	1		1	2
Black petrel		1		1
Sooty shearwater			1	1

Fishing vessels within FMA10 As for the CMA (see above), one incidental problem associated with commercial fishing is birds landing or striking ships that are brightly lit at night for night-time sets. Seabirds can also land on vessels (including fishing vessels) moving through northern New Zealand waters, at times to be found only at destination ports during quarantine searches (B. Lummis, DOC, pers. comm., 12 September 2007).

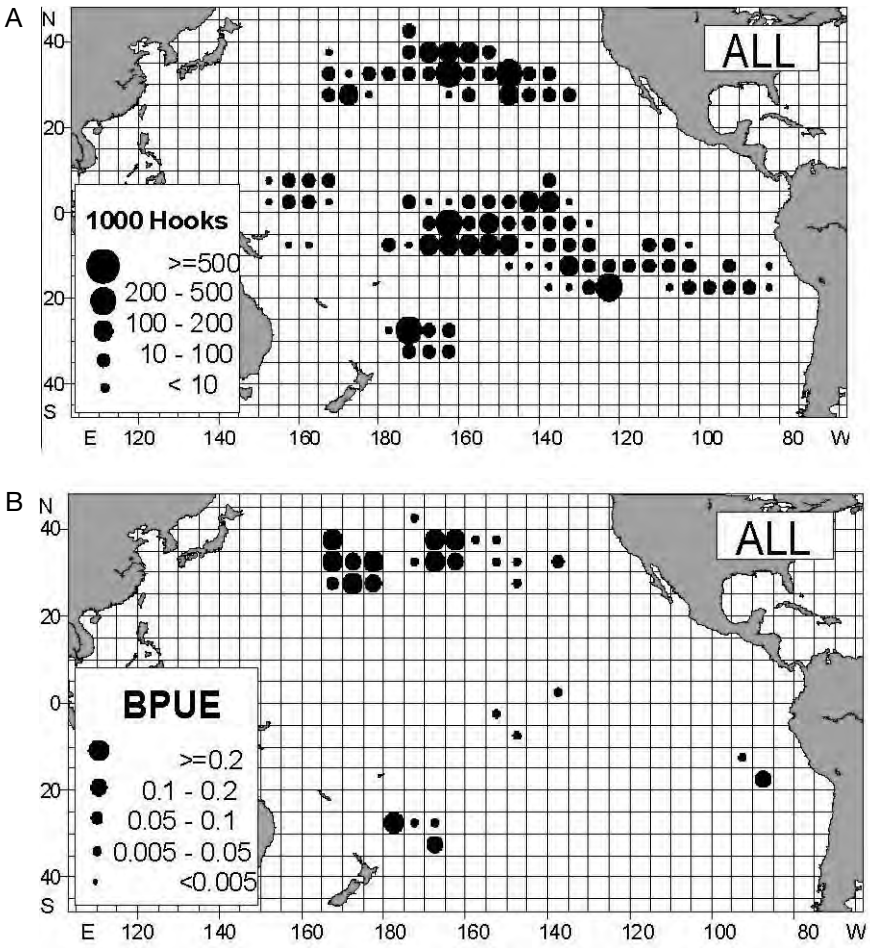

Figure 21. A. Distribution of observed fishing efforts of Taiwanese long-line fisheries in the Pacific Ocean between 2002 and 2006; and B. Distribution of seabird incidental catch BPUE (= number of bycatch per thousand hooks) by Taiwanese long-line fishing vessels in the Pacific Ocean between 2002 and 2006. (Source: Huang et al. 2008.)

Competition with, and habitat depletion by, commercial fisheries Commercial fishing may also have indirect, adverse effects on protected species, such as depleting their food and modifying the habitat important for all or part of their life cycle and behaviour (DOC 2008). For example, in the tropical and subtropical waters of the Pacific Ocean, where many seabirds rely on subsurface predators (particularly tuna), those predatory fish are targeted by fisheries. Where these fish become locally depleted, seabirds such as shearwaters, terns and noddies could experience reduced foraging opportunities (Hebshi et al. 2008).

5. Conclusions

The Kermadec Islands form a seabird refuge of major international importance (Taylor 2000a; Arnold 2004). They are remote, largely uninhabited oceanic islands surrounded by moderately productive waters and are predator free. The Kermadec Islands Marine Reserve, extending out to 12 n.m. around each of the islands (i.e. the Kermadec Islands CMA), is a no-take reserve—one of the world's largest. Seabirds, with their seamless linking of land, sea and air, help to define the natural character of both the islands and the surrounding CMA:

- Seabirds act as major ecosystem drivers on these isolated islands.
- Most Kermadec seabirds are tropical or subtropical taxa, a major point of difference with the rest of New Zealand's seabird fauna.
- The Kermadec Islands are the key breeding site for a number of New Zealand's endemic seabirds, i.e. the white-naped petrel, Kermadec little shearwater and Kermadec storm petrel. The islands are also the only place in New Zealand where ten other species breed, and hold the world's largest population of black-winged petrels.
- All seabirds breeding at the Kermadecs utilise the CMA and the waters immediately adjacent to them for foraging, feeding, resting, preening and bathing.
- Kermadec waters are also used by seabirds that breed outside the region.
- The areas of greatest use by seabirds that forage within the CMA are those areas of upwelling and current activity around islands, and in these areas the seabirds feed in association with subsurface predators. Further offshore, areas of productivity become increasingly ephemeral and less predicable.
- The most important foraging strategy of a number of Kermadec seabirds is to feed in multi-species flocks associated with subsurface predators (e.g. tuna, dolphins).
- The remainder of Kermadec seabirds are pelagic, ranging widely for food, although they take advantage of food found close to the islands owing to the region's bathymetry and oceanographic processes.
- Seabird populations are dependent on a healthy marine ecosystem and, with growing populations in the wake of eradication programmes, there is an imperative to better understand the dynamics at play across the whole region, including fisheries interactions and influences. Seabirds also target productive marine habitats, where they integrate ecological signals, presenting useful biological indicators for understanding variation in marine productivity through space and time. Bird-borne tracking studies for Kermadec seabirds are required to further research seabird foraging and to better understand both seabird ecology and the region's marine environment.
- Raoul Island was historically a site of huge populations of shearwaters, petrels and terns. Since predator and pest eradication, seabirds are starting to recolonise the island. The former huge population of summer-breeding Kermadec petrels, alongside a large winter-breeding population, possibly may be genetically distinct and Raoul Island is the only site in the world where this divergence may have occurred.
- Ongoing monitoring for Kermadec seabirds is urgently required to establish accurate population estimates and detect trends. DOC has established a presence/absence monitoring system for seabirds on around 25% of Raoul Island, which is currently being undertaken at the same time as the weed eradication programme. It is important that surveying of the seabirds on the rest of Raoul Island and on all the other islands in the group is undertaken on a regular basis to ensure recovery of the populations of seabirds, particularly species most at risk and endemic to the region. Of equal importance is the requirement to ensure that biosecurity is maintained on all islands in the group—this could be undertaken at the same time as seabird censuses. Monitoring should be undertaken at 5-yearly intervals.

- The ecological restoration that has been carried out on Raoul and Macauley Islands to date is a major conservation achievement, and the islands' ongoing protection requires a long-term commitment to conservation from government agencies. Enforcement of strict biosecurity protocols is of paramount importance. Maritime misadventure (e.g. shipwreck), unauthorised landings and failure to follow quarantine protocols pose the most significant threats to seabird recovery on these islands.

6. Acknowledgements

This work has been accomplished for the Aquatic and Threats Unit (formerly Marine Conservation Unit), Department of Conservation (Investigation Number 4044). I wish to express my gratitude to Ian West, Clinton Duffy and Karen Baird (former Programme Manager, Kermadec Islands) of the Department for their support of this project; to the Raoul Island 2008 team members for their hospitality and assistance in the field; to Sandy Bartle, Jean-Claude Stahl, Ricardo Palma, Jennifer Twist and Gillian Stone at Museum of New Zealand Te Papa Tongarewa for access to collections material, considerable discussion and generously supplying references; to Brian Gill for access to Auckland Museum collections; to Robert Prys-Jones, Mark Adams and Katrina Cook for access to collections at British Natural History Museum, Tring; to Jean-Claude Thibault, Josh Adams, Bill Sykes, Bill Bourne, Paul Scofield, Steve Chiswell, Suze Baird and Stephanie Rowe for providing data, information and/or discussion on various topics; to Craig Loveridge at the Information Management Group, Ministry of Fisheries, for assistance with fisheries data; to Anna and Chris Wild for their work with the maps; to Pip Forer for graphics presentation; to Dick Veitch, Steffi Ismar and Mark Hauber for their encouragement at various stages; and to Ian Wright and John Mitchell for allowing my participation on the Tangaroa Kermadec Ridge (2007) Expedition (NIWA). Also, my thanks to the crews of various vessels during collection of at-sea observations. Graeme Taylor, Colin Miskelly, the late Mike Imber and Karen Baird provided valuable comments and suggestions on early drafts. This report benefited greatly by the contributions of two anonymous reviewers. Most of all my thanks (posthumously) to John Jenkins for amassing such an extraordinary collection of seabird observations—the heart of this report.

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Appendix 1

List of common and scientific names for all taxa mentioned in this publication

COMMON NAME	SCIENTIFIC NAME
Antarctic prion	*Pachyptila desolata*
Antipodean albatross	*Diomedia antipodensis antipodensis*
Arctic skua	*Stercorarius parasiticus*
Australasian gannet	*Morus serrator*
Black noddy (white-capped noddy)	*Anous minutus minutus*
Black (Parkinson's) petrel	*Procellaria parkinsoni*
Black shag	*Phalacrocorax carbo novaehollandiae*
Black-backed gull	*Larus dominicanus*
Black-bellied storm petrel	*Fregetta tropica*
Black-browed albatross	*Thalassarche melanophris*
Black-winged petrel	*Pterodroma nigripennis*
Blue petrel	*Halobaena caerulea*
Bottlenose dolphin	*Tursiops truncatus*
Broadbill swordfish	*Xiphias gladius*
Broad-billed prion	*Pachyptila vittata*
Brown booby	*Sula leucogaster*
Brown noddy (common noddy)	*Anous stolidus pileatus*
Buller's albatross	*Thalassarche bulleri*
Buller's shearwater	*Puffinus bulleri*
By-the-wind sailor	*Velella velella*
Campbell black-browed albatross	*Thalassarche impavida*
Cape petrel	*Daption capense*
Christmas Island shearwater	*Puffinus nativitatis*
Common dolphin	*Delphinus delphis*
Cook's petrel	*Pterodroma cookii*
Crested tern	*Sterna bergii cristata*
Cyperus	*Cyperus ustulatus*
Diving petrel	*Pelecanoides* sp.
Dog	*Canis lupis familiaris*
Fairy prion	*Pachyptila turtur*
Feral cat	*Felis catus*
Feral goat	*Capra hircus*
Feral pig	*Sus scrofa*
Fiji petrel	*Pseudobulweria macgillivrayi*
Fire ants	*Solenopsis* spp.
Flesh-footed shearwater	*Puffinus carneipes*
Fluttering shearwater	*Puffinus gavia*
Flyingfish	Exocoetidae
Flying squid	Onycoteuthidae
Galapagos shark	*Carcharhinus galapagensis*
Giant petrel sp.	*Macronectes* sp.
Gibson's albatross	*Diomedia antipodensis gibsoni*
Gould's petrel	*Pterodroma leucoptera leucoptera*
Great frigatebird	*Fregata minor palmerstoni*
Grey noddy (grey ternlet)	*Procelsterna cerulea albivittata*
Grey petrel	*Procellaria cinerea*
Grey-faced petrel	*Pterodroma macroptera gouldi*
Henderson petrel	*Pterodroma atrata*

Continued on next page

Appendix 1—continued

COMMON NAME	SCIENTIFIC NAME
Herald petrel	*Pterodroma heraldica*
Ice plant (native)	*Disphyma australe*
Jellyfish	*Porpita* sp.
Juan Fernandez petrel	*Pterodroma externa*
Karaka	*Corynocarpus laevigatus*
Kermadec little shearwater	*Puffinus assimilis kermadecensis*
Kermadec red-crowned parakeet	*Cyanoramphus novaezelandiae cyanurus*
Kermadec petrel	*Pterodroma neglecta neglecta*
Kermadec pōhutukawa	*Metrosideros kermadecensis*
Kermadec storm petrel	*Pelagodroma albiclunis*
Kingfish	*Seriola grandis*
(Sacred) Kingfisher	*Todiramphus sanctus*
Little tern	*Sternula albifrons*
Long-tailed cuckoo	*Eudynamys taitensis*
Long-tailed skua	*Stercorarius longicaudus*
Magenta petrel (tāiko)	*Pterodroma magentae*
Mahimahi	*Coryphaena hippurus*
Masked (Tasman) booby	*Sula dactylatra tasmani*
Mottled petrel	*Pterodroma inexpectata*
Murphy's petrel	*Pterodroma ultima*
New Caledonian petrel	*Pterodroma leucoptera caledonica*
New Zealand sooty tern	*Onychoprion fuscata serratus*
New Zealand storm petrel	*Pealeornis maoriana*
Ngaio	*Myoporum rapense* subsp. *kermadencense*
North Island little shearwater	*Puffinus assimilis haurakiensis*
Northern giant petrel	*Macronectes halli*
Norway rat	*Rattus norvegicus*
Pacific (northern Buller's) albatross	*Thalassarche bulleri platei*
Pacific rat (kiore)	*Rattus exulans*
Parapara	*Pisonia umbellifera*
Phoenix petrel	*Pterodroma alba*
Pilot whale	*Globicephala melas*
Pōhutukawa	*Metrosideros excelsa*
Portuguese man o'war	*Physalia physalis*
Providence petrel	*Pterodroma solandri*
Pūkeko	*Porphyrio melanotus melanotus*
Pycroft's petrel	*Pterodroma pycrofti*
Rats	*Rattus* spp.
Red-billed gull	*Larus novaehollandiae scopulinus*
Red-footed booby	*Sula sula*
Red-tailed tropicbird	*Phaethon rubricauda*
Sea striders	*Halobates sericeus*
Shining cuckoo	*Chrysococcyx lucidus lucidus*
Short-tailed shearwater	*Puffinus tenuirostris*
Skipjack tuna	*Katsuwonus pelamis*
Snapper	*Chrysophrys auratus*
Snowy (wandering) albatross	*Diomedia exulans*
Soft-plumaged petrel	*Pterodroma mollis*
Sooty shearwater/muttonbird/tītī	*Puffinus griseus*
South Island saddleback	*Philesturnus carunculatus*
Southern black-backed gull	*Larus dominicanus dominicanus*
Spotless crake	*Porzana tabuensis tabuensis*
Spotted black grouper	*Epinephelus daemelii*
Stejneger's petrel	*Pterodroma longirostris*
Subantarctic (brown) skua	*Catharacta antarctica lonnbergi*

Continued on next page

Appendix 1—continued

COMMON NAME	SCIENTIFIC NAME
Subantarctic little shearwater	*Puffinus elegans*
Tahiti petrel	*Pseudobulweria rostrata*
Thin-billed (slender-billed) prion	*Pachyptila belcheri*
Tūī	*Prosthemadera novaeseelandiae novaeseelandiae*
Wahoo	*Acanthocybium solandri*
Wedge-tailed shearwater	*Puffinus pacificus pacificus*
Welcome swallow	*Hirundo neoxena*
White tern	*Gygis alba candida*
White-bellied storm petrel	*Fregetta grallaria grallaria*
White-capped albatross	*Thalassarche cauta*
White-chinned petrel	*Procellaria aequinoctialis*
White-faced storm petrel	*Pelagodroma marina*
White-fronted tern	*Sterna striata*
White-headed petrel	*Pterodroma lessonii*
White-naped petrel	*Pterodroma cervicalis*
Wilson's storm petrel	*Oceanites oceanicus*
Yellowfin tuna	*Thunnus albacares*

Appendix 2

Distributions of Kermadec seabirds

See Appendix 1 for scientific names of taxa. Only references are provided for the Identification section. All maps have their vertical axes parallel to north–south. Map legends indicate number of records.

Order: Procellariiformes—albatrosses, petrels, prions, shearwaters and storm petrels

Family Procellariidae

WEDGE-TAILED SHEARWATER

Identification: Marchant & Higgins 1990a; Brooke 2004; Onley & Scofield 2007.

Distribution: Wedge-tailed shearwaters breed throughout tropical and subtropical Pacific and Indian Oceans, and are believed to be weakly migratory. They are absent from breeding islands during the non-breeding season (Onley & Scofield 2007). Figure A2.1 highlights the occurrence of wedge-tailed shearwaters across South Pacific waters and well to the west of the Kermadec Islands during their breeding season. It also shows that, at other times of the year, wedge-tailed shearwaters have been recorded near colonies at the Kermadecs, Fiji and Tonga, although they are largely absent from large areas of ocean. Birds from these island groups are believed to migrate towards the central northern Pacific Ocean during the non-breeding season (Jenkins 1979b; Onley & Scofield 2007).

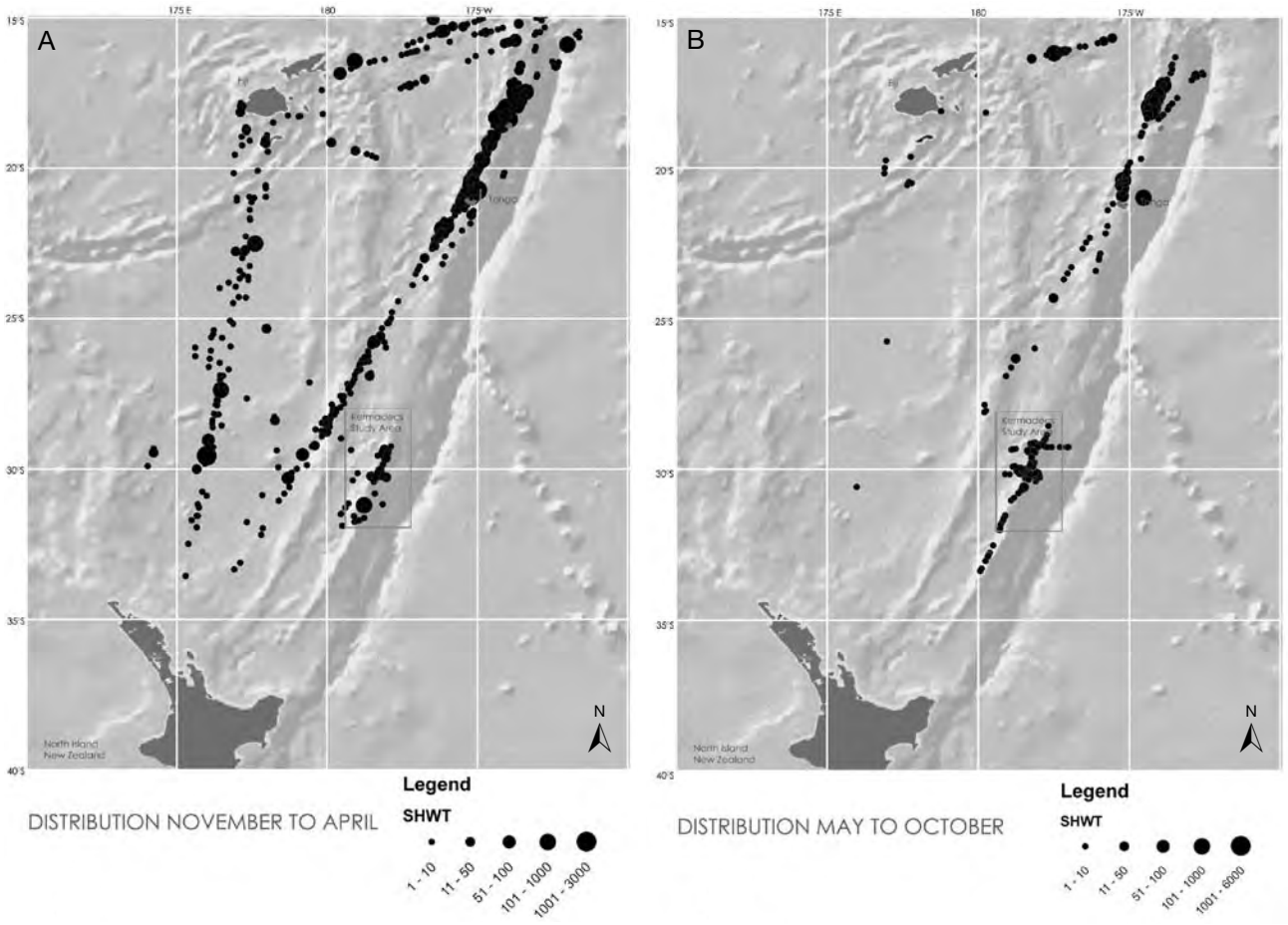

Figure A2.1. Distribution of the wedge-tailed shearwater. A. November–April, and B. May–October (1969–2008).

KERMADEC LITTLE SHEARWATER

Identification: Marchant & Higgins 1990a; Brooke 2004; Onley & Scofield 2007.

Distribution: The Kermadec little shearwater is endemic to the Kermadec Islands. Other subspecies of little shearwater are found elsewhere, including *haurakiensis*, which breeds in northern New Zealand, and *assimilis*, which breeds on Norfolk and Lord Howe Islands (Onley & Scofield 2007). The subantarctic little shearwater breeds in the subantarctic islands in the Pacific and Atlantic Oceans. Dispersal of little shearwaters is very poorly known, with few records of birds away from breeding grounds during the non-breeding season. Figure A2.2 shows records of little shearwaters from colonies on either northern New Zealand offshore islands (*P. a. haurakiensis*) or the Kermadec Islands (*P. a. kermadecensis*).

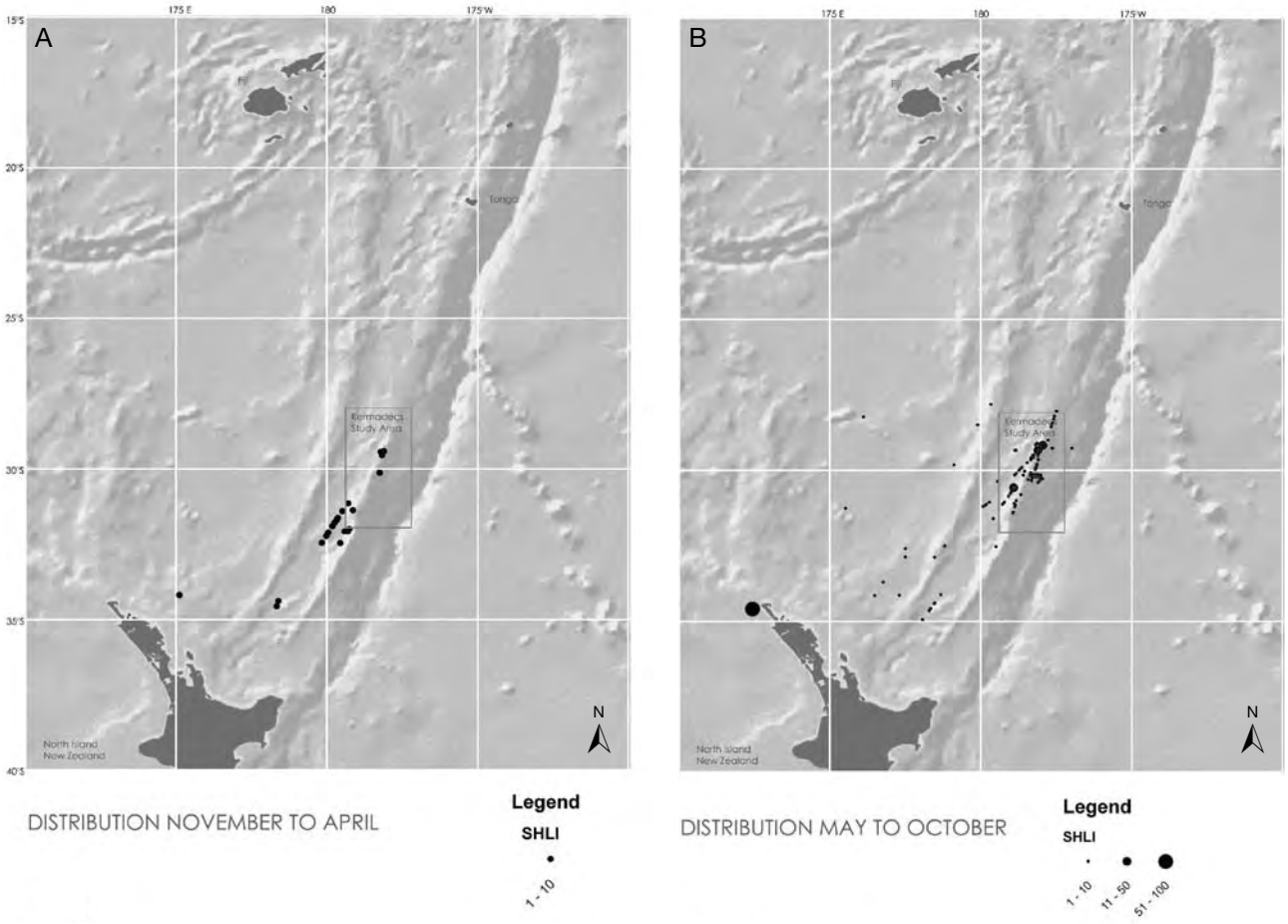

Figure A2.2. Distribution of the Kermadec little shearwater. A. November–April, and B. May–October (1969–2008).

WHITE-NAPED PETREL (= WHITE-NECKED OR SUNDAY ISLAND PETREL)

Identification: Marchant & Higgins 1990a; Brooke 2004; Onley & Scofield 2007.

Distribution: This species is endemic to the Kermadec Islands. During the breeding season, it ranges towards New Zealand and the Tasman Sea, and some Pacific islands (Tonga, Fiji), as is highlighted in Fig. A2.3. It migrates through the tropical Pacific Ocean to the Pitcairn Islands (CG, pers. obs., 2006, 2007) and towards Hawaii (King 1970). During May–October, white-naped petrels have been recorded in waters adjacent to the Kermadec Islands; a number of these records are for May and will include breeding birds at the end of the breeding season. The distribution of records in Fig. A2.3B possibly reflects the species' dispersion into tropical waters after breeding.

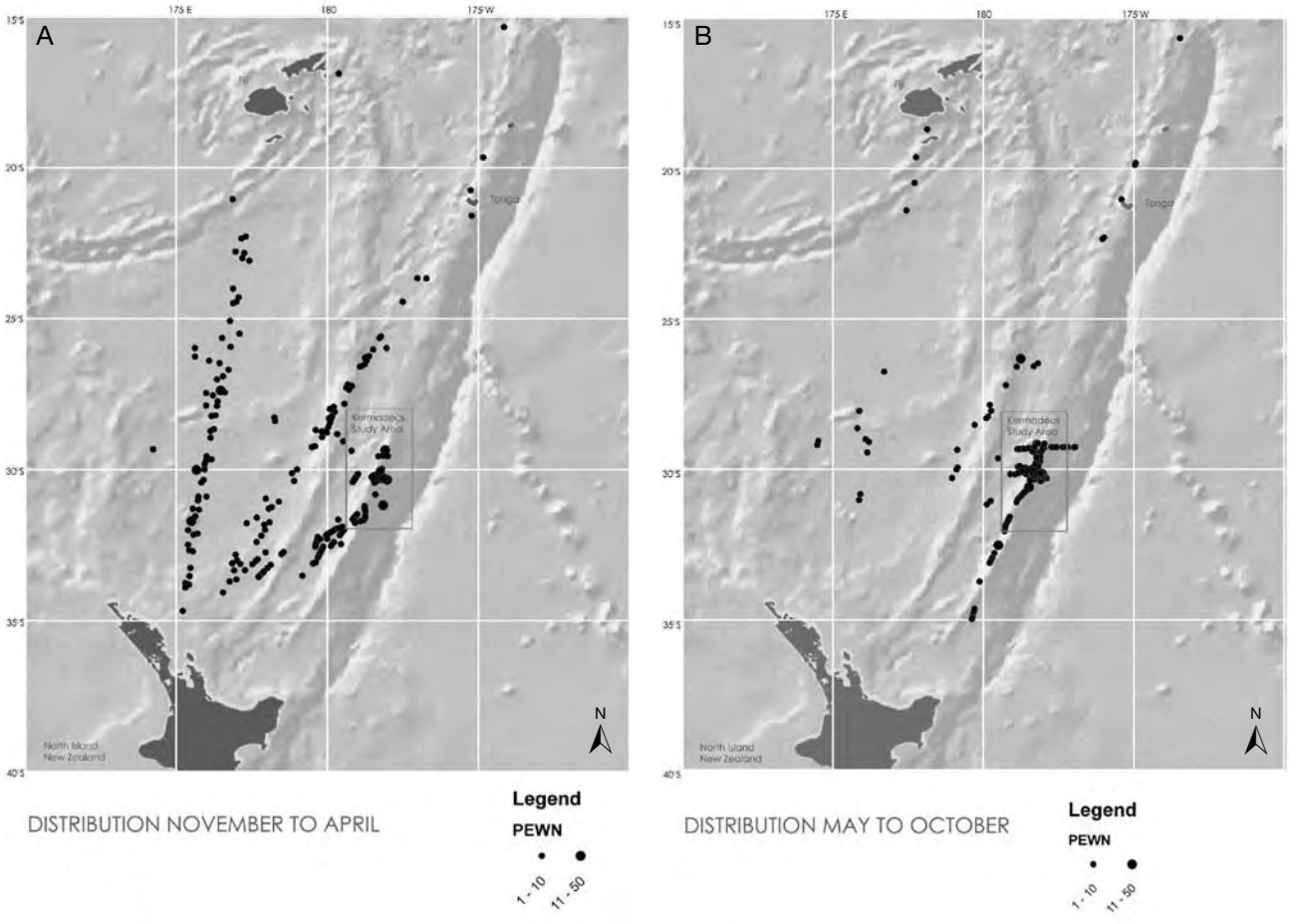

Figure A2.3. Distribution of the white-naped petrel. A. November–April, and B. May–October (1969–2008).

KERMADEC PETREL

Identification: Marchant & Higgins 1990a; Brooke 2004; Onley & Scofield 2007.

Distribution: This species breeds in the subtropical (Austral Islands) and tropical (Pitcairn Islands) Pacific Ocean, and in the Indian Ocean on Round Island. As described in section 4.5.2, most are 'winter-breeding' birds, although a small number of 'summer-breeding' birds are known for the Meyer Islands (Imber 2005). Figure A2.4 shows records of Kermadec petrels scattered widely during November–April, but closer to (i.e. < 500 km away from) the Kermadec Islands during May–October. Both maps in the figure highlight the Kermadec petrel's pelagic habit, with some sightings less than 50 km from colonies, and including large numbers of birds flying back and forth between islands and feeding areas.

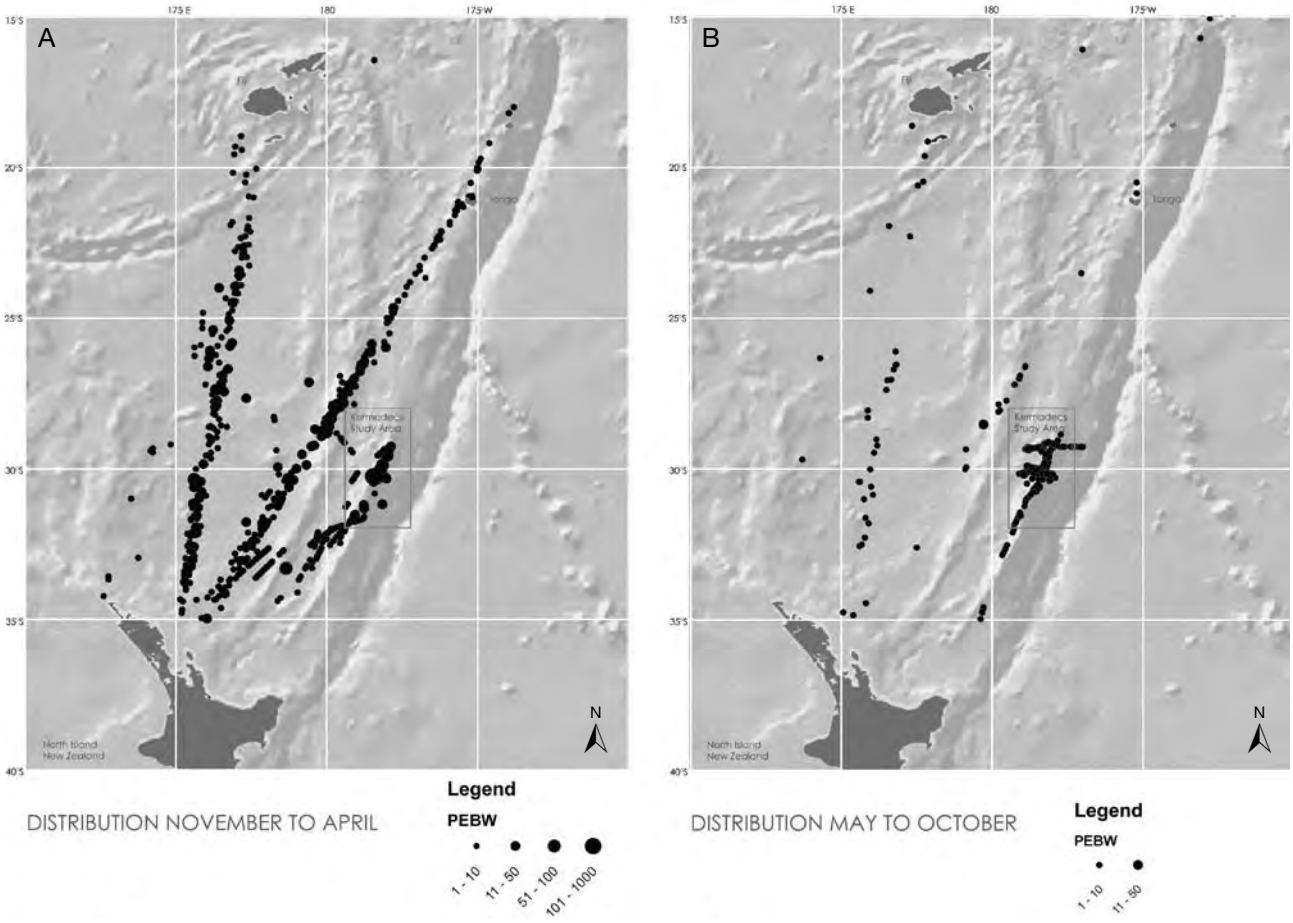

Figure A2.4. Distribution of the Kermadec petrel. A. November–April, and B. May–October (1969–2008).

BLACK-WINGED PETREL

Identification: Marchant & Higgins 1990a; Brooke 2004; Onley & Scofield 2007.

Distribution: Records for this species are concentrated in the southwest Pacific Ocean during the breeding season, with the birds foraging widely in subtropical seas around the Kermadecs over the summer months (Fig. A2.5A). The species is abundant in the northwest Pacific during July–September (Tanaka et al. 1985), central Pacific (Jenkins & Cheshire 1982) and the tropical eastern Pacific (Pitman 1986), all of which is consistent with the relative absence of black-winged petrels from the Kermadec waters during the non-breeding months (Fig. A2.5B).

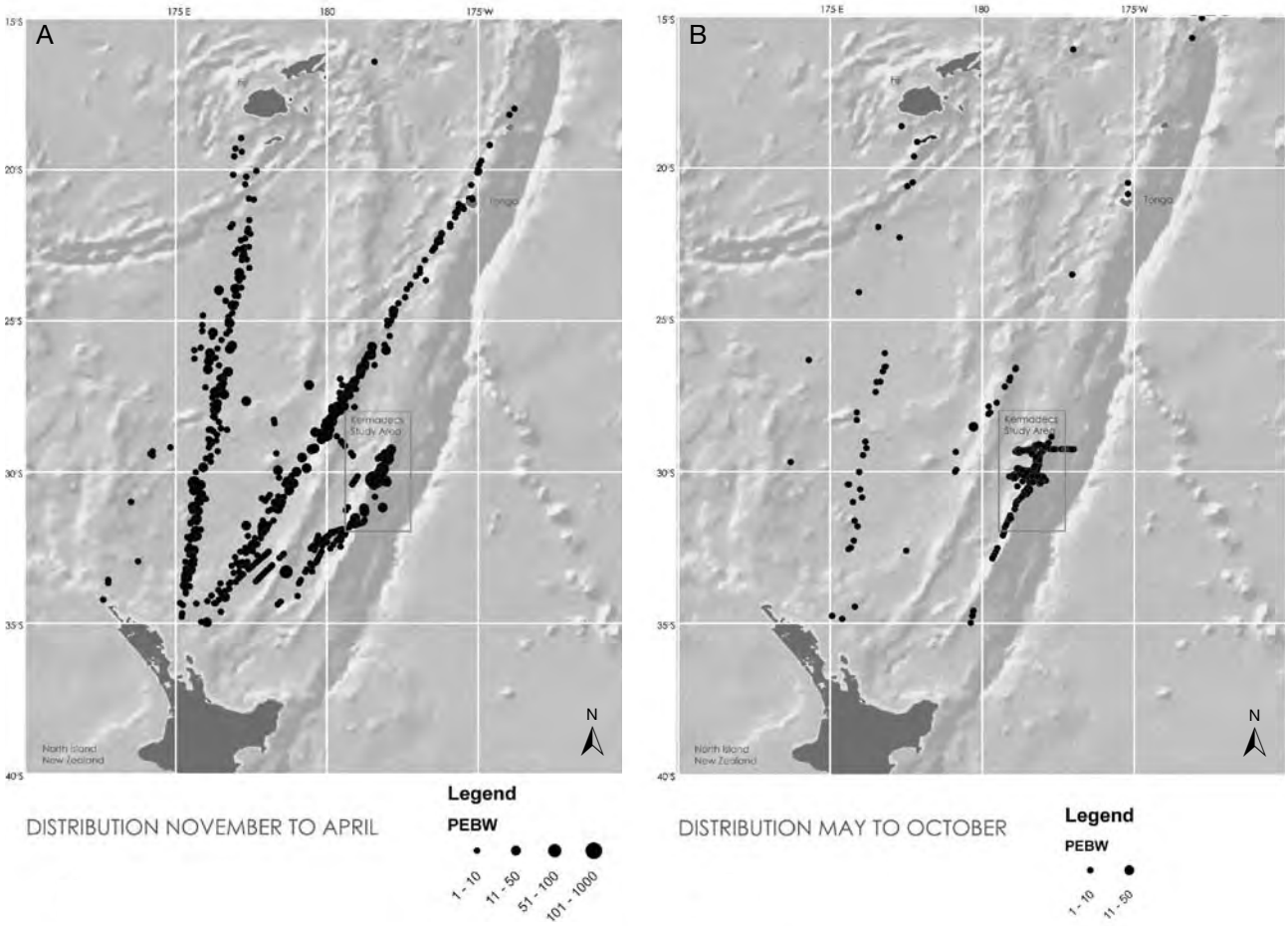

Figure A2.5. Distribution of the black-winged petrel. A. November–April, and B. May–October (1969–2008).

Family: Hydrobatidae; Subfamily: Oceanitinae

WHITE-BELLIED STORM PETREL

Identification: Marchant & Higgins 1990a; Brooke 2004; Onley & Scofield 2007.

Distribution: This and related subspecies breed on subtropical islands in the Pacific, Atlantic and Indian Oceans, with the white-belled storm petrel breeding on the Kermadec and Lord Howe Islands. Movements of the birds are poorly known, although a recent record (July 2008) of white-bellied storm petrels in Fiji waters (D. Watling, pers. comm., 22 March 2009) may indicate that it disperses into tropical waters at that time. Records confirm the presence of white-bellied storm petrels in the wider Kermadec area (all records are < 250 km from colonies) during October–May (Fig. A2.6).

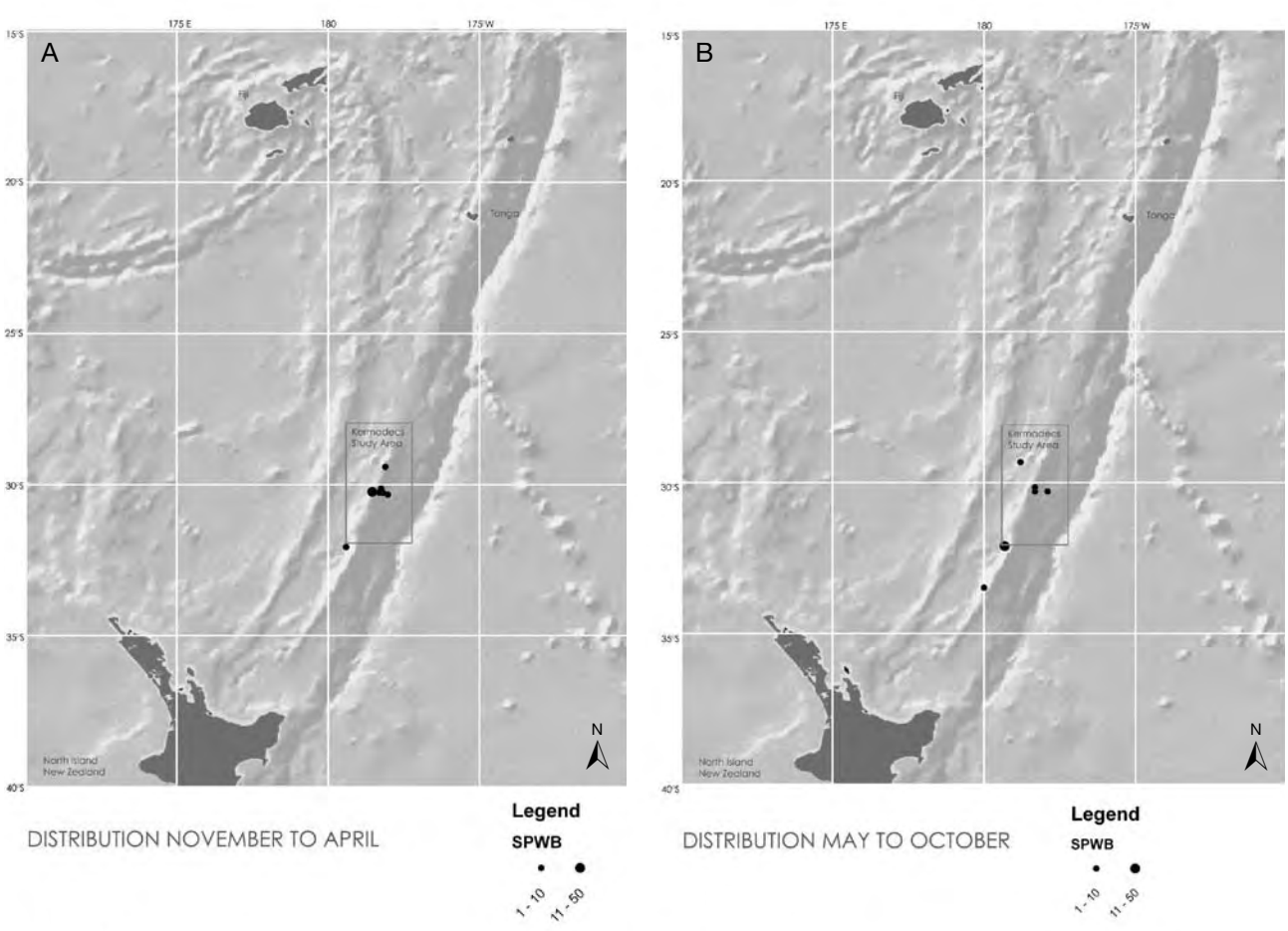

Figure A2.6. Distribution of the white-bellied storm petrel. A. November–April, and B. May–October (1969–2008).

KERMADEC STORM PETREL

Identification: Marchant & Higgins 1990a; Brooke 2004; Onley & Scofield 2007.

Distribution: The Kermadec storm petrel is present in Kermadec waters from May (CG, pers. obs., 2007) to November (Imber 2004) and appears to be absent in January (CG, pers. obs., 2006). Jenkins (1982) observed four storm petrels with white rumps and faces off the New South Wales coast in October 1981, which may have been this species (from his description), although it seems more likely that they were white-faced storm petrels (note: storm petrels with white faces and very pale rumps have been observed in the Hauraki Gulf and are most likely white-faced storm petrels). The maps in Fig. A2.7 show the occurrence of Kermadec storm petrel in the region, with its presence confirmed in the vicinity of the Kermadec Islands only for May–November.

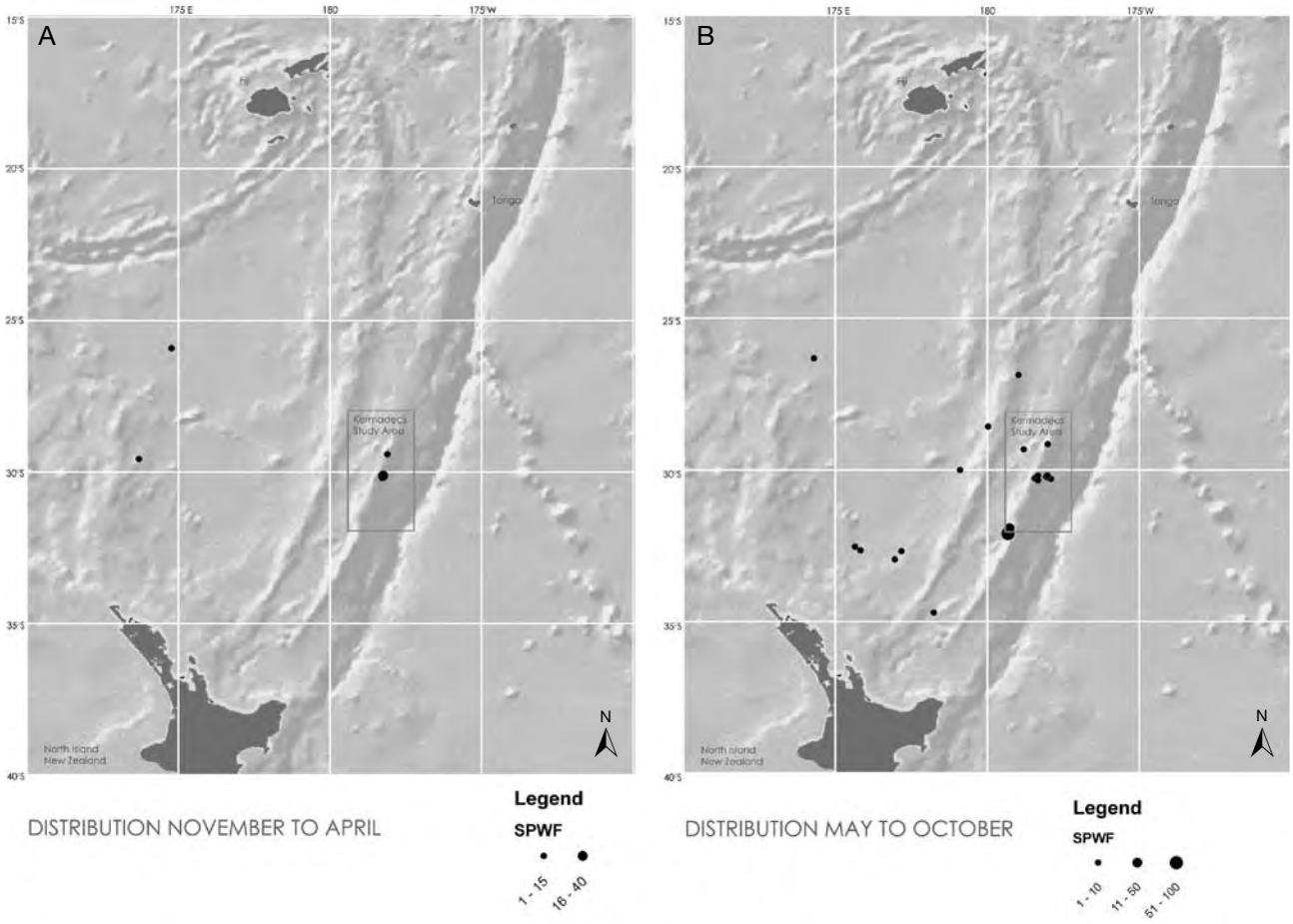

Figure A2.7. Distribution of the Kermadec storm petrel. A. November–April, and B. May–October (1969–2008).

Order: Pelecaniformes—pelicans, gannets, cormorants and allies

Family: Sulidae

MASKED BOOBY (= TASMAN BOOBY)

Identification: Marchant & Higgins 1990a; Heather & Robertson 1996.

Distribution: The masked booby is widespread in tropical waters c. 30°N–30°S, including Tonga, where it is the rarest of the boobies breeding there. It breeds on Lord Howe, Norfolk and Kermadec Islands. The birds are migratory or dispersive, with Kermadec birds found in Vanuatu and New Caledonia. During the breeding season, they forage well offshore, although they are commonly seen feeding within sight of colonies when in Kermadec waters. The few records are well spread across the region (the low numbers reflecting the relatively small populations), with numbers increasing in the vicinity of known breeding colonies (e.g. Kermadec Islands). The map of observations outside the breeding season (Fig. A2.8B) may include birds from Kermadec, Norfolk and Lord Howe populations.

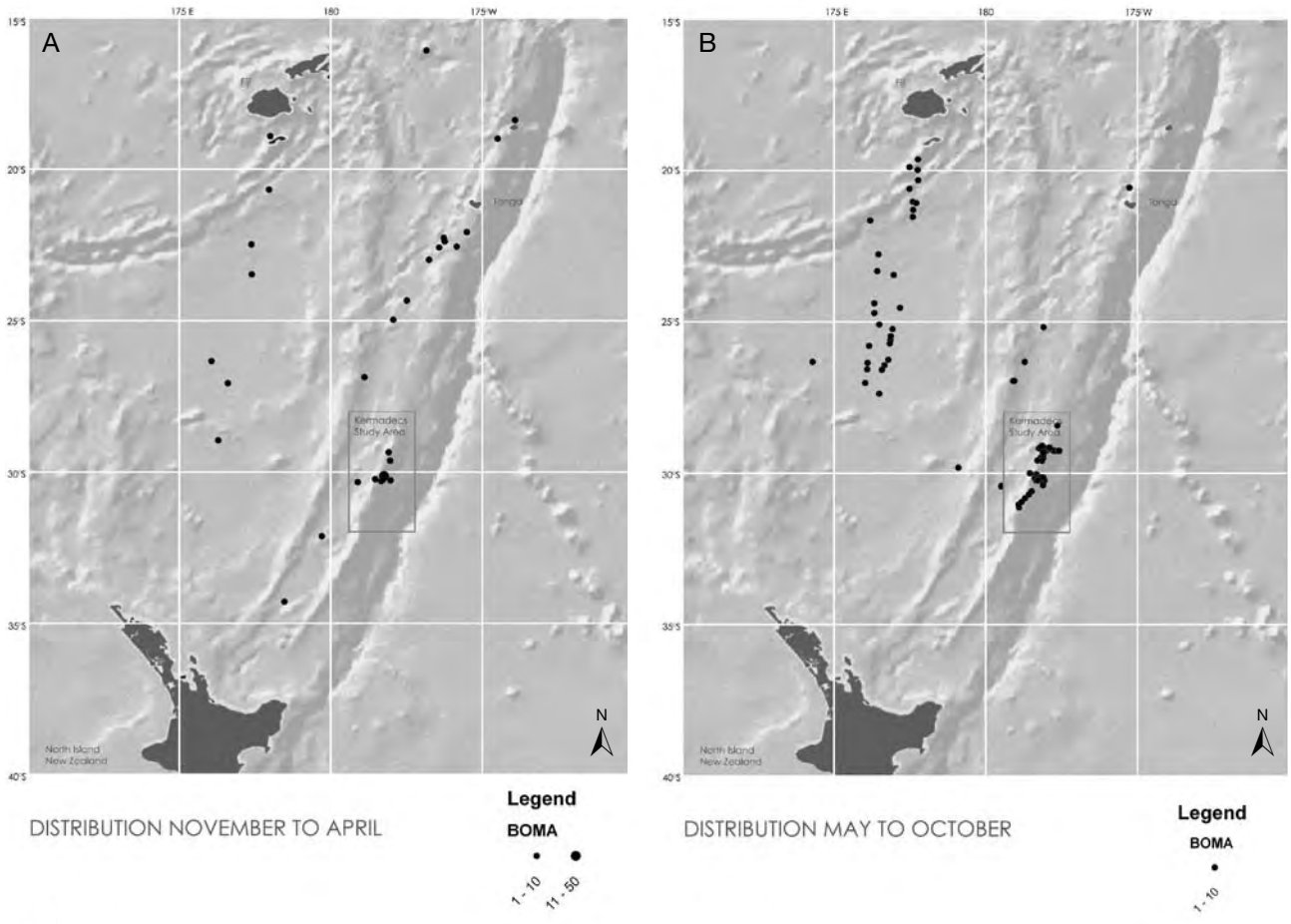

Figure A2.8. Distribution of the masked booby. A. November–April, and B. May–October (1969–2008).

Order: Phaethontiformes—tropicbirds

Family: Phaethontidae

RED-TAILED TROPICBIRD

Identification: Marchant & Higgins 1990b; Heather & Robertson 1996.

Distribution: Red-tailed tropicbirds breed in the tropical and subtropical Pacific and Indian Oceans. In the southwest Pacific region specifically, they breed on Lord Howe and Norfolk Islands, and are dispersive or migratory (but patterns of movements away from the breeding sites are not known). They may remain within the same latitudinal range all year, although there is some evidence for trans-equatorial movement (Marchant & Higgins 1990b). Birds have been recorded in northern New Zealand waters during the summer and autumn months (Heather & Robertson 1996; I. Southey, pers. comm., 7 April 2009; CG, pers. obs., 2007) (Fig. A2.9). Occurrences of the birds in Fiji waters during winter months requires further investigation; this species has not been confirmed breeding there (D. Watling, pers. comm., 22 March 2009).

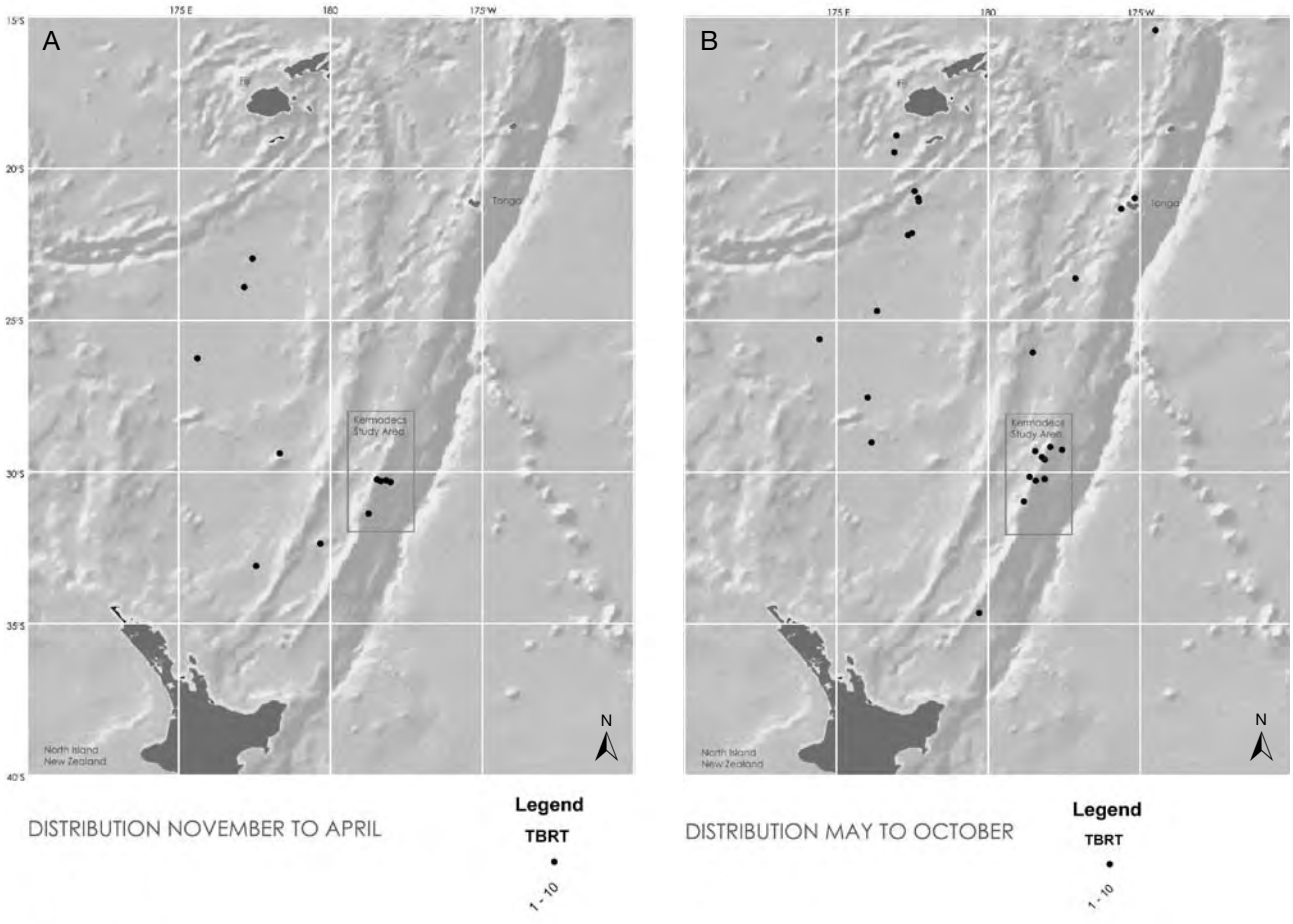

Figure A2.9. Distribution of the red-tailed tropicbird. A. November–April, and B. May–October (1969–2008).

Order: Charadriiformes—waders, gulls and terns

Family: Sternidae

SOOTY TERN

Identification: Higgins & Davies 1996; Heather & Robertson 1996.

Distribution: Sooty terns breed in the subtropical and tropical regions of the Pacific, Indian and Atlantic Oceans; the New Zealand sooty tern is found only on the Kermadec Islands. The birds depart from the Kermadec colonies following breeding (by the end of May) (DOC *Raoul Island Thirdly Reports*). They are likely to be strongly pelagic during the non-breeding season. Records of sightings shown in Fig. A2.10 are consistent with these findings, with birds distributed across a wide area west of the Kermadec Islands, presumably foraging pelagically, during the breeding season and absent from the area during non-breeding months.

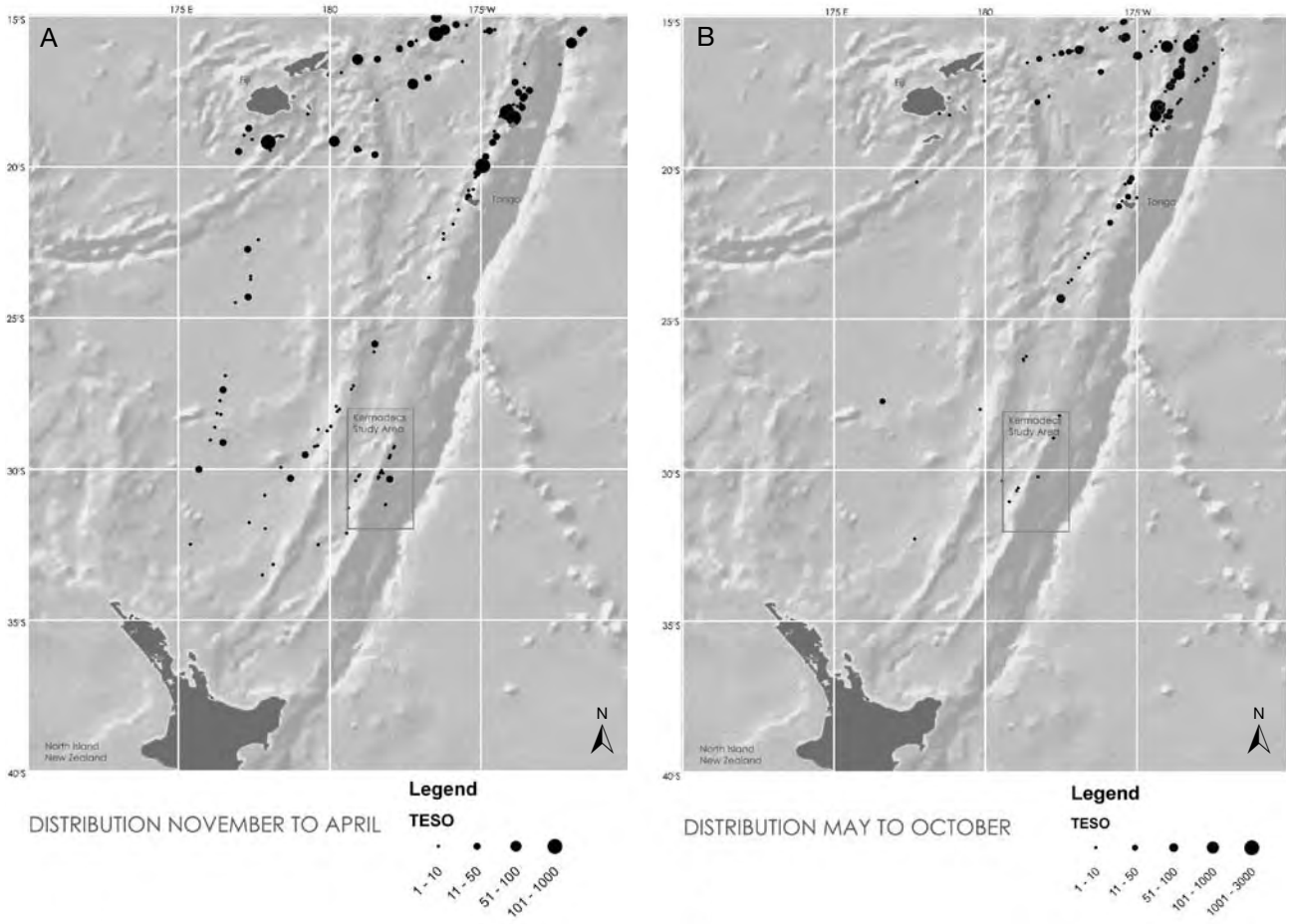

Figure A2.10. Distribution of the sooty tern. A. November–April, and B. May–October (1969–2008).

BLACK NODDY (= WHITE-CAPPED NODDY)

Identification: Higgins & Davies 1996; Heather & Robertson 1996.

Distribution: The black noddy breeds mainly in the Pacific Ocean, with small, scattered populations in the Indian and Atlantic Oceans, including the Caribbean Sea. Nominate *minutus* breeds from Pitcairn Islands to Australia, including the Lord Howe, Norfolk and Kermadec Islands. The species has also been recorded from the New Zealand mainland. The birds are considered sedentary, with most populations remaining on their breeding islands throughout the year (Higgins & Davies 1996), which is consistent with the records of black noddies close to breeding islands (see Fig. A2.11).

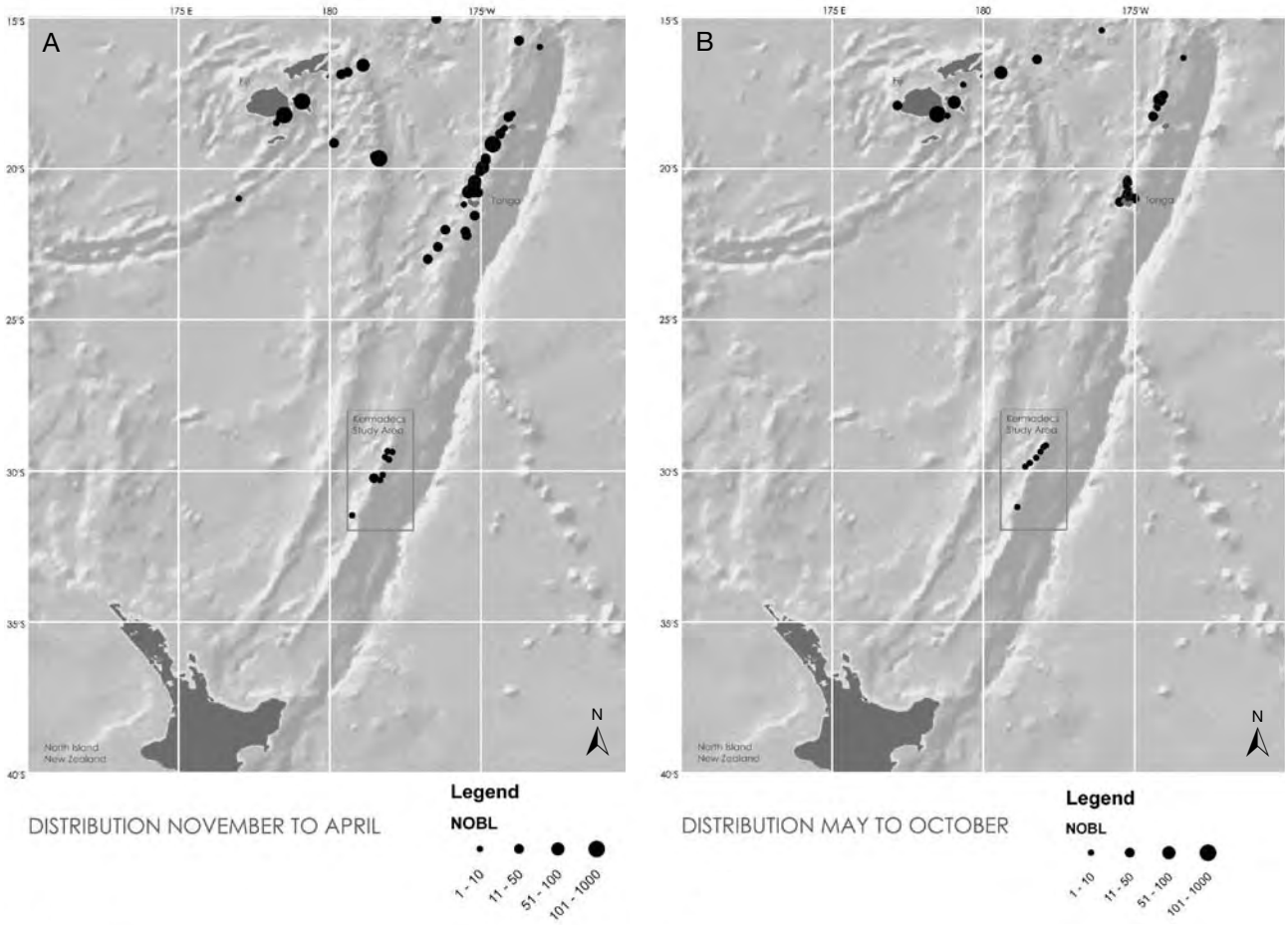

Figure A2.11. Distribution of the black noddy. A. November–April, and B. May–October (1969–2008).

BROWN NODDY (= COMMON NODDY)

Identification: Higgins & Davies 1996; Heather & Robertson 1996.

Distribution: The brown noddy breeds on tropical and subtropical islands in the Pacific, Indian and Atlantic Oceans, with this particular subspecies breeding from the Red Sea to Hawaii, and in the South Pacific, including the Kermadec Islands. The breeding population on Curtis Island is very small compared with the very large colonies in Fiji and Tonga. The maps in Fig. A2.12 confirm this, with only one record for brown noddies at sea in Kermadec waters (Imber 2004).

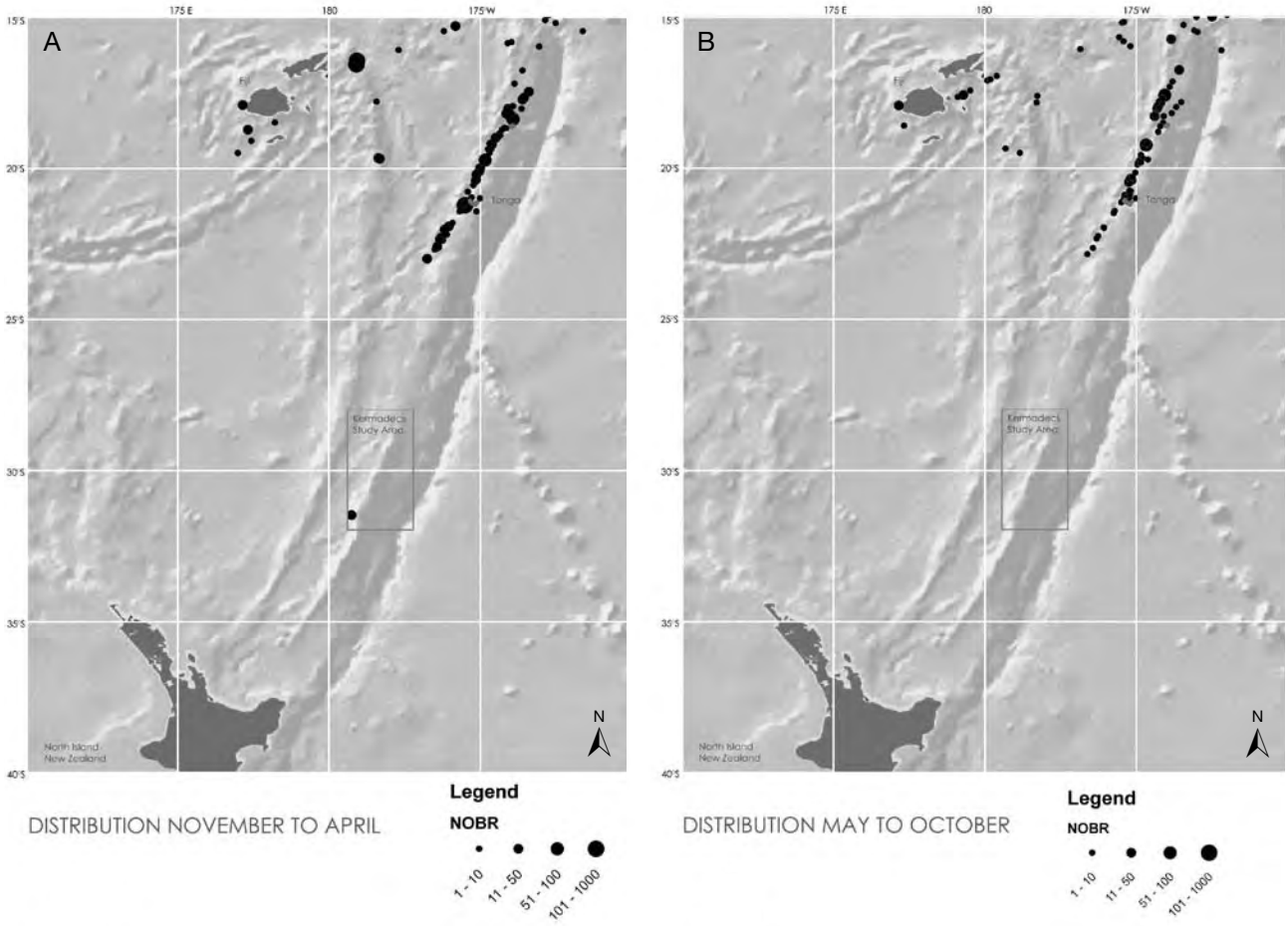

Figure A2.12. Distribution of the brown noddy. A. November–April, and B. May–October (1969–2008).

GREY NODDY (= GREY TERNLET)

Identification: Higgins & Davies 1996; Heather & Robertson 1996.

Distribution: This taxon is found throughout the tropical Pacific Ocean, from Hawaii south to the Kermadec Islands; Lord Howe Island; the Norfolk Islands; the Austral, Gambier and Pitcairn Groups; and Islas Desventuradas. Birds have been observed at sea between the Kermadec Islands and the North Island during January (Fig. A2.13A), and are known to roost on stacks (November–April) along New Zealand's northern coast. Outside the breeding season, the birds stay close to the Kermadec Islands for the most part (Fig. A2.13B), although two records, one to the northwest of the island group and the other well to the west, may indicate dispersal away from islands. Grey ternlet records for Fiji Islands are suggestive of their breeding there, although this has never been confirmed (D. Watling, pers. comm., 22 March 2009).

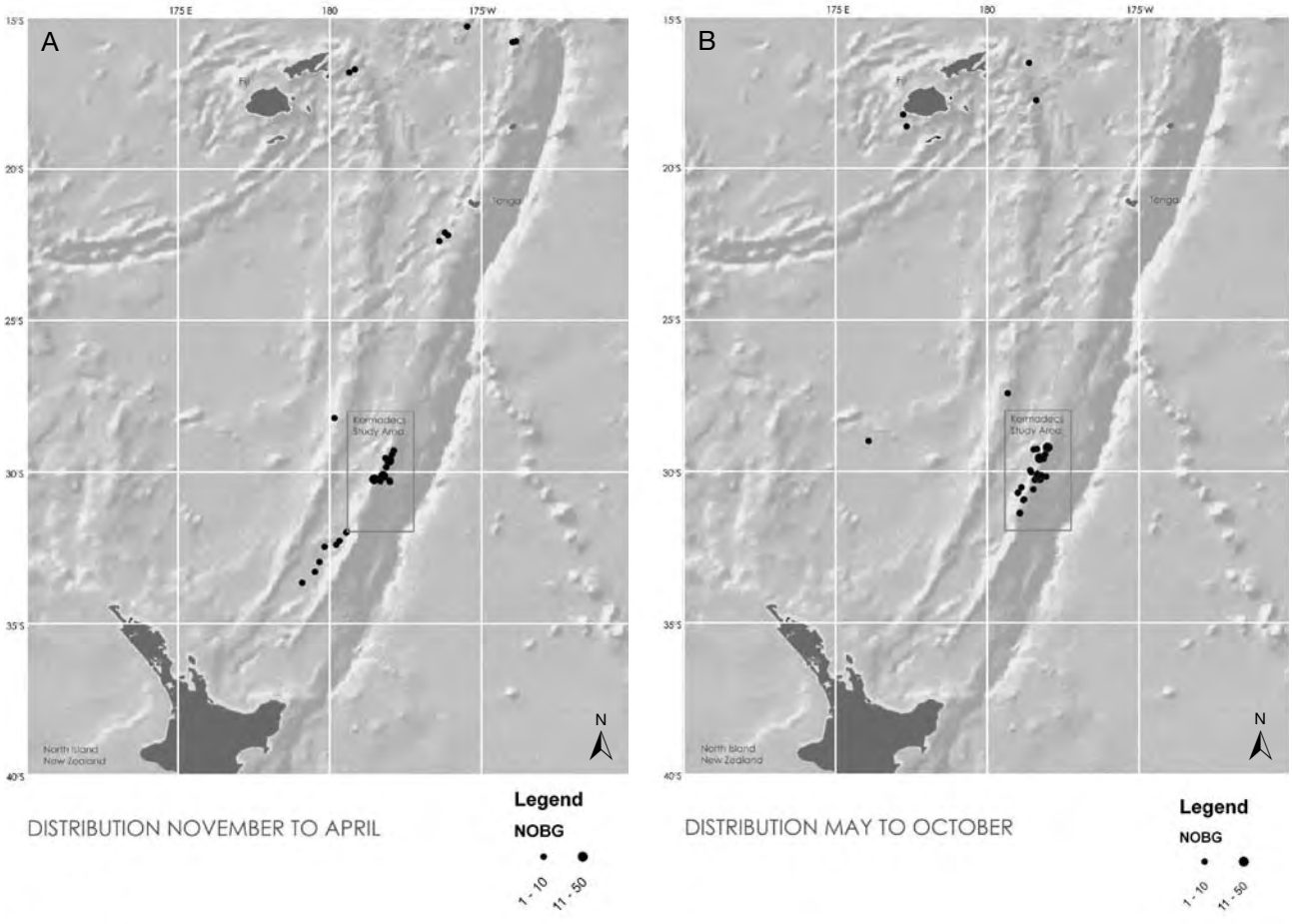

Figure A2.13. Distribution of the grey ternlet. A. November–April, and B. May–October (1969–2008).

WHITE TERN

Identification: Higgins & Davies 1996.

Distribution: The white tern breeds throughout the Pacific and Indian Oceans, with populations in the Atlantic Ocean. There is a much-reduced population on Raoul Island, and larger colonies on Norfolk and Lord Howe Islands. Birds have been observed off North Cape (North Island) in January (CG, pers. obs.), and in March–June, including birds beach-wrecked on the North Island (Heather & Robertson 1996). Formerly, birds seen close to the New Zealand mainland could have included Kermadec birds; however, with Raoul Island's much reduced population, recent records are more likely to be of birds from Norfolk Island or, possibly, further afield (Fig. A2.14). White terns are believed to disperse to pelagic waters outside the breeding season.

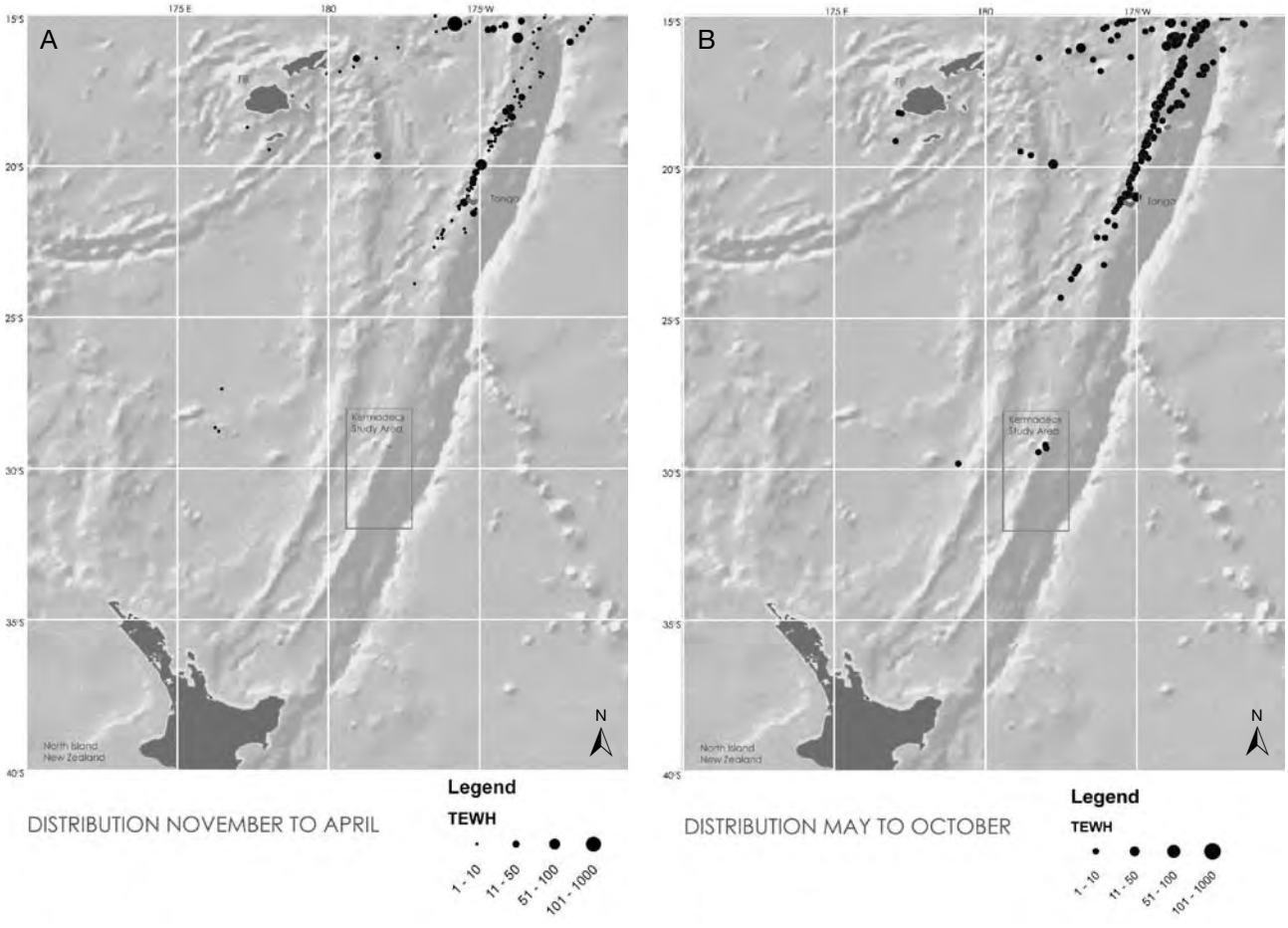

Figure A2.14. Distribution of the white tern. A. November–April, and B. May–October (1969–2008).

Appendix 3

Estimated numbers of seabirds breeding on the Kermadec Islands

Numbers are pairs, unless otherwise stated.
Sources: Taylor 2000a,b; Veitch et al. 2004; Ismar et al. 2010; CG, pers. obs.

	RAOUL I.	MEYER IS & HERALD ISLETS	MACAULEY I. & HASZARD ISLET	CURTIS I.	CHEESEMAN I.	L'ESPERANCE ROCK
Island size (ha)	2943	52	324	53	9	5
Wedge-tailed shearwater	<50 (2008)	c. 10000 (1970)	c. 40000 (1988)	c. 2500 (1989)	<500	<50 (1988)
Kermadec little shearwater	Extirpated	1000+	c. 500 (1988)	c. 100000 (1989)	<1000 (1989)	
White-naped petrel	Extirpated		c. 50000 (1988)			
Kermadec petrel	Extirpated	c. 6000 (1970)	<50 (1988)			
Black-winged petrel	<1000 (2008)	1000+ (1970)	c. 2500000 (1988)	c. 300000 (1989)	10000+ (2002)	200 (1988)
Kermadec storm petrel	Extirpated	<100	c. 200 (2006)			
White-bellied storm petrel	Extirpated		<200 (2002)	<500 (1988)	<100 (2002)	
Red-tailed tropicbird	<50 (2008)	<1000 (2007)	<500 (2007)	c. 20 (1989)		
Masked (Tasman) booby	Nil	c. 200	c. 100 (1988)	c. 100 nests (2002)	<20	2 nest sites occupied (2002)
Sooty tern	5000 (1994)	10000 (1988)	Nine colonies were found (1988), 10000 eggs counted	5500 (1989)	5000 (1970)	
Brown noddy	Nil			c. 25 (1989)		
Black noddy	Nil	1000 (1967)	50 (1988)	40 (1989)	20 (1970)	30 (1970)
Grey noddy (grey ternlet)	Nil	5000+	10000 (1988)	5000 (1989)	1000	1000–1500 (1988); 2000+ birds roosting (2006–2008)
White tern	<15 (2008)					

Appendix 4

Abridged field notes from two sea voyages (January 2006, May 2007) by Chris Gaskin

A4.1 All birds seen at sea 4–18 May 2007

Starting at 140 n.m. SW of Macauley and ending in the same area (200 n.m. SW of Macauley) on the return journey to Wellington; * denotes confirmed breeding on Kermadec Islands:

Gibson's albatross: Adults, immatures and juveniles seen 18 May on return journey.

Antipodean albatross: One seen 36 n.m. SE of Macauley Island 10 May.

Black-browed albatross: (Immature) three sightings, all possibly the same bird W of Raoul 6, 7 May; one bird seen W of Macauley Island 11 May; one subadult seen S of Macauley (between Macauley and Cheeseman Islands) 17 May.

Black (Parkinson's) petrel: Several sightings, with up to five at one location 50 n.m. E of Raoul 8 May; seen at several locations in the vicinity of Macauley Island 10, 11 May.

Wedge-tailed shearwater:* Common, seen all days, close to and distant (up to 60 n.m.) from Raoul and Macauley Islands; saw immature booby attacking a young shearwater in the water near Macauley Island (fledged chicks are leaving the colony and we saw three that were unable to fly off the water).

Kermadec little shearwater:* One seen W of Raoul 6 May; eight seen just N and E of Raoul 8 May, the last two c. 46 n.m. E of Raoul; common between Raoul and Macauley Islands 9 May; seen in numbers approaching Macauley from the E 10 May; saw 100+ actively foraging across an area immediately W and NW of the Meyer and Herald Islands on 12 May when we picked up the scientific party from Raoul; saw 100+ (in small groups or individually) foraging over a wide area 2–5 n.m. NE of Macauley Island.

Sooty shearwater: Five seen between Raoul and Macauley Islands 9 and 11 May; one seen just N of Raoul 12 May.

Buller's shearwater: Two seen early evening E of Macauley Island 14 May.

White-naped (white-necked) petrel:* Very common, seen all days; some sightings very close to Raoul in the early evening 6 May.

Kermadec petrel:* Very common, seen all days; the many observations of Kermadec petrels made during this voyage offered the ideal opportunity to study plumage variation that is such a feature for this species, particularly as possible confusion exists between Kermadec petrels and a number of other species, namely: Tahiti petrel , phoenix petrel, Herald petrel , Henderson petrel, magenta petrel (tāiko), white-headed petrel, soft-plumaged petrel, providence petrel and grey petrel. All three phases were seen (light-pale white-headed phase, intermediate and dark, with some birds 'smudgy', i.e. between intermediate and dark). White primary shafts visible on all birds where upperwing was visible (a consistent feature).

Black-winged petrel:* Abundant, seen all days, particularly close to islands; two birds collected on board at night showed extensive down; a third bird collected from the water also showed down but was clearly weak and later died aboard.

Gould's/New Caledonian petrel: Several seen, singly at close range from the bow 6, 7 May W of Raoul Island and 9 May immediately NE of Macauley Island; three seen (singly) 18 May SW of Cheeseman and Curtis Islands.

Grey-faced petrel: Common, seen all days; especially common over deep water E of Raoul and around Macauley Island; birds seen exhibited a range of plumages from dark chocolate brown (almost black in some lights) with little or no pale grey face, through to dark grey-brown including dark face.

***Pterodroma* sp.:** A single, striking, ashy-grey, all-dark bird was seen between Macauley and Raoul Islands 11 May. This bird was identified as *P. gouldi* on the basis of head-shape and solid-looking bill, despite its plumage colouration being in marked contrast to a 'regular' dark grey-brown grey-faced petrel seen moments later. Murphy's petrel (*P. ultima*) is the only grey, all-dark *Pterodroma*; however, the bill appeared too heavy for *ultima* and the bird lacked the M-marking on the upper surfaces, although that feature can be indistinct on *ultima*.

***Pterodroma* sp.:** One cookilaria petrel with light markings on underwing seen very briefly W of Raoul Island 7 May.

***Pachyptila* sp. or *Pterodroma* sp.:** One unidentified bird was seen 16 May N of Macauley Island with pale-grey (prion-like) plumage on the head and mantle and prominent upperwing markings (M); a cookilaria-sized bird. Underparts, face and tail were not seen clearly before the bird disappeared into the sun's glare. A momentary flash of a dark marking on the underwing would suggest a *Pterodroma*.

Thin-billed prion: Although not seen in the vicinity of Raoul and Macauley, two, possibly three, were seen 150–200 n.m. S of Macauley 18 May.

Kermadec storm petrel:* One seen close to Raoul and Meyer Islands (2 n.m.); six seen approaching Macauley from the SE 10 May (36, 10 and 4 n.m. from the island); one seen 4.5 n.m. E of Macauley 14 May; one seen S of Macauley 17 May; also one bird seen 50 n.m. W of Raoul 7 May in rough seas, rump not seen so unable to separate this subspecies from white-faced storm petrel. When seen well, *P. m. albiclunis* appeared to be in fresh plumage with very prominent pale wing bars (along the greater secondary coverts) standing out against the dark primaries and the grey of the rest of the upper wing and mantle; conspicuous white rump. Also seen in numbers 140 n.m. SW of Macauley 4 May.

White-faced storm petrel: Seen in numbers 140 n.m. SW of Macauley 4 May (as above). These birds, having grey rumps, contrasted with the Kermadec storm petrel, i.e. lacked the conspicuous white rump. None were seen close enough to distinguish between the slightly forked tails of the *maoriana* subspecies and the more-square tails of *dulciae* (Marchant & Higgins 1990a).

White-bellied storm petrel:* One seen 50 n.m. W of Raoul 7 May; one seen 36 n.m. SE of Macauley Island 10 May; one seen E of Macauley Island 14 May; one seen 6 n.m. NE of Macauley 17 May. A freshly dead fledgling was collected on Macauley Island by the geology party 17 May. Also seen in numbers 140 n.m. SW of Macauley 4 May (as above).

Black-bellied storm petrel: Two, possibly three, seen 50 n.m. W of Raoul 7 May; two more seen 36 n.m. SE of Macauley Island. These birds can be described as follows: a fairly solid-looking, medium-sized black-and-white storm petrel that bounded across the waves, wings held horizontal with occasional gliding, no pattering or hovering with wings uplifted; black head and breast with white along flanks and a very prominent irregular black belly line (seen on all three birds); upperwing with soft grey across the coverts. All features above plus wing shape are consistent with this species (*F. tropica*). However, the underwings in the two cases when seen well revealed white to pale-grey centre in a predominantly dark underwing (this pale area did not extend beyond the secondary coverts). Such an underwing plumage pattern is inconsistent with *F. tropica*, with only white-bellied storm petrel (intermediate form) and Wilson's storm petrel (very occasionally) among taxa for this region known to have a pale grey central underwing area (in some cases close to white). Both these can be ruled out, however. No white-bellied storm petrels have a dark central belly line and intermediate forms have dark plumage along the flanks with central belly area white or pale grey; Wilson's storm petrel have very different behaviour, flight,

body and wing shape, and the extent of white on the underparts is not quite as extensive, even on those specimens with some pale plumage on the underwing. The conclusion here is that these birds were black-bellied storm petrel, possibly just-fledged birds from the Antipodes Islands, which are darker ventrally than those on the Auckland Islands (M. Imber, pers. comm., 18 May 2007). One, possibly two, birds were seen on 18 May 150 n.m. SW of Macauley Island.

Wilson's storm petrel: A number were seen 140 n.m. SW of Macauley 4 May on the voyage up amongst a large feeding group that included white-bellied, white-faced and Kermadec storm petrels.

Red-tailed tropicbird:* Several seen, usually singly and in the vicinity of the Meyers and Raoul Islands; up to 30 seen flying around and over Macauley; fledglings seen from the vessel sitting on ledges in gully areas.

Masked booby:* Common within 10 n.m. of Raoul, some would follow or bow-ride the boat; also in good numbers near Macauley Island. A mix of young birds and adults were seen; of particular interest was one group that had been flying above the bow, which set off in noisy pursuit of a flying fish.

White tern:* Several seen on the W side of Raoul 6 May.

Black noddy:* One seen 6 May feeding with grey ternlets within 1 n.m. from northwestern headland of Raoul; one seen close to Macauley Island 15 May.

New Zealand sooty tern:* One seen 15 n.m. NE of Macauley Island 17 May.

Grey ternlet (blue-grey noddy):* Common inshore (i.e. close to islands); also a number seen approaching Raoul Island 7 May either individually or in small numbers flying towards the island from open waters to the W; one seen just S of Raoul Island 11 May; group of 30 on a stack next to Haszard Island 14 May; seen in small groups flying from E towards Macauley Island 15, 16 and 17 May.

Black-backed gull: One immature bird seen 5 n.m. W of Macauley Island; this bird was on the water but took off with the approach of the vessel and flew past; appeared very thin, especially when seen end-on as it approached boat.

Welcome swallow: Three stayed with the vessel from the North Island to Raoul; one was seen while the vessel was W of Raoul 5 May but not seen after that.

A4.2 All birds seen at sea 12–19 January 2006

We boarded MV *Braveheart* at Tauranga at 11 p.m., joining the five crew members for a private trip to the Kermadec Islands. The Kermadecs are 2 ½ days steaming at 9–10 knots (about 800 km) northeast of the North Island. The legs up and back gave us a chance to trial a couple of seabird counting methods: one sent to us from NOAA (part of their ecosystems studies programme for the eastern Pacific), the other from guidelines for the Australasian Seabird Mapping Scheme courtesy of Sandy Bartle (Museum of New Zealand Te Papa Tongarewa). With the 6-day trip the plan was to get up to the Kermadecs, spend a full day (stretched to a couple of days) in the area and head home. Briefly, we reached the Star of Bengal Bank in the afternoon of the 14th. This is a set of seamounts to the south of L'Esperance Rock, the southernmost 'island' in the group. The 15th was spent in the vicinity of Macauley Island, first following a line out towards the Kermadec Trench, then heading back to the island, circumnavigating it slowly throughout the afternoon with a number of stops until just after sunset before heading for Raoul after dark. Most of the 16th was spent at Raoul, both on shore while we off-loaded gear for the Department of Conservation (DOC) team based on the island, and among the Meyer, Herald and Chanter Islands close by using a zodiac. By evening, we were again off Macauley and well on our way home. The 17th was a whole day at sea. The 18th was again at sea and then we decided we would make a stop at White Island for a look around later in the afternoon. We reached Tauranga and docked at 5 a.m. on the 19th. Weather was superb, with calm conditions or light airs for 5 of the 6 days—amazingly, given the Kermadecs usually get lapped by cyclones at this time of the year.

A summary of species seen follows:

Gibson's (wandering) albatross: Juveniles, immatures and adults, with most seen south of the Kermadecs.

Antipodean (wandering) albatross: Two seen.

Snowy (wandering) albatross: One possible immature.

White-capped albatross: 1

Black-browed albatross: 1

Pacific albatross: 1

Northern giant petrel: 1

Black (Parkinson's) petrel: Seen all the way to the Kermadecs and back again, with most below 35°S.

White-chinned petrel: One seen going north.

Grey-faced petrel: Seen in good numbers all the way to Kermadecs; a number of dark-faced grey-faced petrels, especially in the day south of the Kermadecs.

Kermadec petrel: Off Macauley in open sea and in the vicinity of Raoul, especially over the Meyer Islands and Napier Island.

White-naped (white-necked) petrel: Started seeing these on the second day going up, in big numbers from Star of Bengal Bank and to north of Macauley. On the way back we saw our last white-naped petrels (two of them) at 36°S (i.e. within a day's sailing from Tauranga).

Cook's petrel: Many mostly east of the Coromandel Peninsula and Great Barrier Island (Aotea Island), basically south of 35°S.

Pycroft's petrel: A number were identified among the Cook's.

Black-winged petrel: Started picking these up from day 2 onwards (i.e. north of 35°S).

Gould's/New Caledonian petrel: One seen and photographed during a chumming session just south of Star of Bengal Bank (probably a New Caledonian bird).

Unidentified small all-dark petrel: Seen in vicinity of Star of Bengal Bank; slightly smaller than a black-winged petrel. Note: the only small all-dark petrels are Bulwer's petrel, dark-phase collared petrel and the extremely rare Fiji petrel.

Buller's shearwater: Like Cook's petrels, these dropped out at around 35°S.

Flesh-footed shearwater: Mostly on the first morning when we were east of the Coromandel Peninsula.

Sooty shearwater: Two seen.

Fluttering shearwater: Only in the Bay of Plenty, first morning, and just north of White Island on last day.

Little shearwater: One seen just north of White Island; no Kermadec little shearwaters seen.

Wedge-tailed shearwater: Seen north of 30°S on both legs.

White-faced storm petrel: Seen on first and last days; no Kermadec storm petrels—we felt sure that had Kermadec storm petrels been off Macauley and the Meyers, we would have seen them; after our experience with New Zealand storm petrels, strange to have in view 30+ black-and-white storm petrels (in this case white-bellied); to be keenly searching for white-faced storm petrels was a novel experience for us; it is thought that these birds breed on Macauley, with Meyer Islands another possibility; we did not get the chance to spend time near to Curtis and Cheeseman Islands, another possible breeding location for these birds.

White-bellied storm petrel: Seen only in the vicinity of Macauley, at locations over deep water (2000 m) or at locations closer to the islands; we would have seen about 50 during the day we spent within sight of Macauley.

Common diving petrel: First and last days only.

Grey ternlet: Many close to Macauley and Raoul (especially feeding in the current lines between the Meyer and Herald Islands). Also saw them over open sea, including one bird (flying like a *Pterodroma*) on the last day, 36°S.

Black noddy: Good numbers around Macauley and Raoul, also over open sea between the islands.

Sooty tern: As above.

White-fronted tern: Seen on first and last days only.

Red-tailed tropicbird: Seen in vicinity of Macauley and Raoul (especially over Meyer Islands and also 'washing' in the sea between Herald islands and Raoul).

Australasian gannet: Seen on first and last days only; spectacular around White Island, with the colonies scattered along the south coast of the island.

Masked booby: In the vicinity of the Kermadecs only.

Frigatebird sp.: Three or four seen amongst the birds over Napier and Meyer Islands.

Arctic skua: One seen on day 2.

Long-tailed skua: One seen on day 1.

Black-backed gull: White Island only.

Red-billed gull: One seen at Kermadecs, otherwise in the vicinity of White Island.

Other marine life included:

Unidentified whale: One large rorqual (brief sighting on the first day in moderately rough conditions).

Common dolphin: Just north of White Island.

Bottlenose dolphin: At Kermadecs (Macauley and Raoul Islands).

Sharks: The only sharks we saw were Galapagos sharks while snorkeling at the Meyers.

Flyingfish: Large blue flyingfish on every day (appeared to be same species as those seen in the Hauraki Gulf).

Flying squid (Onycoteuthidae): This was something of a revelation for us. Karen Baird (ever the marine biologist) quickly worked out that groups of small strange-looking 'flying fish' we were seeing flying from the sea were in fact squid; through bins you could see that they were translucent, used their fin vanes to glide and ejected a long jet of water to propel themselves.

Salps: Many seen at various times, either from the vessel or while snorkelling off Macauley.