Notornis, 2025, Vol. 72: 23–32 https://doi.org/10.63172/028790seccvg
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Breeding seabird assemblage of Rapa, Austral Islands, Eastern Polynesia

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Abstract: Rapa Island, located in Eastern Polynesia, hosts 12 species of breeding seabirds, now primarily found on its ten peripheral islets. These seabirds face various threats, such as invasive mammals that prey on eggs and chicks, as well as invasive plants that encroach upon and degrade their breeding habitats. Major island restoration projects are currently underway on several islets, focusing on the removal of invasive mammals and plants. We present data collected here between 2017 and 2024 and, together with published and unpublished surveys since 1921, compile details on the distribution, population, and breeding seasons of these seabird species.

Withers, T.; Bretagnolle, V.; Butaud, J.-F.; Cibois, A.; Cranwell, S.; Jacq, F.; Laitame, T.; Luta, R.; Shirihai, H.; Thibault, J.-C. 2025. Breeding seabird assemblage of Rapa, Austral Islands, Eastern Polynesia. *Notornis 72(1)*: 23–32. (https://doi.org/10.63172/028790seccvg).

Keywords: breeding seabirds, Rapa shearwater, Polynesian birds, trend

INTRODUCTION

Rapa (27°35′S 144°20′W) is the southernmost inhabited island of the Austral archipelago, and is surrounded by ten islets (Figs 1 & 2). It is a mountainous volcanic island, with Mount Perau (650 m) as its highest point. Rapa is home to approximately 500 inhabitants, distributed across two villages (A'urei and Area). The island has been relatively well-surveyed by ornithologists due to the presence of two endemic species, a storm petrel and a shearwater (Thibault & Varney 1991; Shirihai *et al*. 2017). Some ornithologists have visited Morotiri (formerly Marotiri), also known as Bass Rocks, located 83 km southeast of Rapa (Gaskin 2007; Flood *et al*. 2021).

Rapa's seabirds face a range of threats, including invasive mammals that prey on eggs and chicks, as well as invasive plants that encroach on breeding habitats and provide additional seasonal food sources for Pacific rat (*Rattus exulans*). Major island restoration projects are currently underway on several islets and the main island, focusing on the removal of invasive mammals and plants. These efforts are managed by the Polynesian Ornithology Society (SOP-Manu) in collaboration with its partners, BirdLife International, and the local Rapa NGO Raumatariki.

Received 6 January 2025; accepted 12 February 2025
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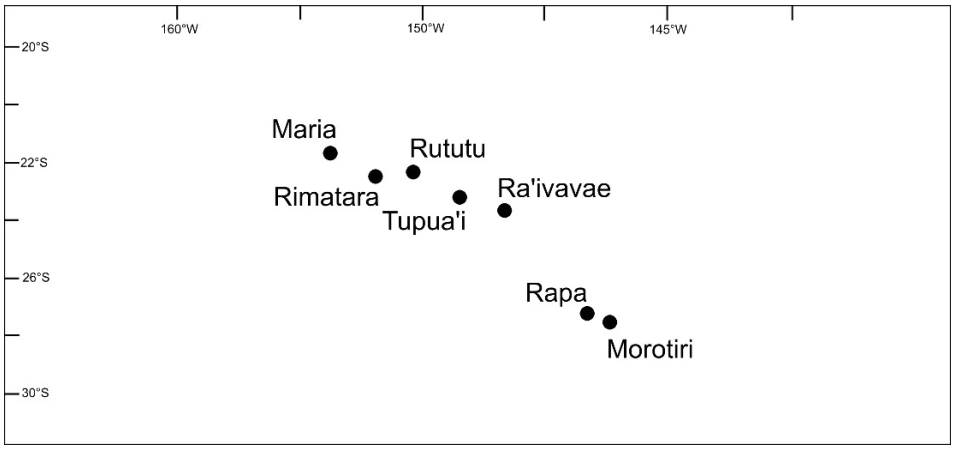


Figure 1. Spatial arrangement of the Austral Islands, showing the locations of Rapa and Morotiri.

Figure 2. Map of Rapa and surrounding islets (islets named in white, not italics).

Since 2017, SOP-Manu has supported the Rapa community in restoring uninhabited islets to protect seabirds by removing goats and working towards the eradication of rats, which was successfully achieved on some islets in November 2023 (Table 1). During this conservation work, additional studies on seabirds were conducted between 2019 and 2024, to further inform strategies for protecting these species in the future.

In this paper, we combine historical and recent findings from Rapa to update the list of 12 breeding seabird species, to provide estimates of their breeding populations, to establish a breeding phenology calendar, and, using sporadic historical data collected over the past century, to infer long-term population trends for these species. None of the seabirds are abundant, including the two local endemics (Rapa shearwater *Puffinus myrtae* and white-bellied storm petrel *Fregetta grallaria titan*), both of which are of conservation concern.

METHODS

Historical visits

In the 19th century, Captain Frederick W. Hutton brought back a fruit dove specimen, which Finsch (1874) described as a new species (*Ptilinopus huttoni*). However, it remains unknown whether other birds, particularly seabirds, were collected during this visit. Vine Hall (1869), in his description of Rapa, only mentions, "*there are a few fowls, wild in the bush* [fruit dove?], *some widgeon* [Pacific black-duck *Anas superciliosa*], *and of course sea-gulls* [noddies and petrels?]." It was not until the Whitney South Seas Expedition (WSSE), organised by the American Museum

Table 1. Characteristics of islets surrounding Rapa (2024 data). Goats have been removed from all islets; however, they remain on Rapa (along with cats, dogs, cows, and horses).

Islet/Island	Area (ha)	Altitude (m)	Distance offshore (m)	Breeding seabirds	Pacific rat presence
Aturapa	1.94	44	187	Yes	Unknown
Karapoo Koio (= Iti)	2.27	130	63	Yes	Absent
Karapoo Rahi (= Nui)	10.21	215	28	Yes	Present
Rapa Iti	4.24	85	57	Yes	Eradicated
Rarapai	1.29	53	115	Yes	Absent
Tapiko	0.32	20	66	Yes	Absent
Tapu'i	0.94	27	141	No	Present
Tarakoi	1.92	64	213	Yes	Absent
Tauturou	20.09	151	383	Yes	Eradicated
Tuamotu	0.29	13	17	No	Unknown
Rapa (main island)	4,000	650		Yes	Present

Table 2. Temporal spread of observation (and specimen collection) dates on Rapa and surrounding islets.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sources and observers
1921				X									WSSE, AMNH (R.H. Beck & E. Quayle)
1922		X											WSSE, AMNH (R.H. Beck & E. Quayle)
1925				X									BMNH (H.J. Kelsall *in* Bourne 1959)
1934												X	BMNH (Crocker Exp.)
1968				X	X								MNHN (Lacan ms)
1974										X	X	X	EPHE-MNHN (J.-C. Thibault *pers. obs*)
1984	X	X											Ehrhardt (1986)
1989												X	Thibault & Varney (1991); Seitre & Seitre (1991)
1990	X												Thibault & Varney (1991)
1993		X											A. Guillemont (*pers. comm*. to VB)
2002			X	X								X	K. Wood (unpubl. data); B. Fontaine (*pers. comm*. to J-CT)
2017			X	X									Butaud *et al.* (2018)
2019			X					X	X		X	X	Thibault & Withers (*pers. obs*), Shirihai (*pers. obs*)
2020							X						Withers *et al.* (*pers. obs*)
2021					X	X							Withers *et al.* (*pers. obs*)
2022							X	X					Withers & Luta (*pers. obs*)
2023				X			X				X	X	Withers *et al.* (*pers. obs*)
2024				X			X			X	X		Withers *et al.* (*pers. obs*)

of Natural History (New York) at the beginning of the 20th century, that the first inventory of the avifauna was conducted. The WSSE visited Rapa 14–20 Apr 1921 and 15–26 Feb 1922. Ernest Quayle (1921, 1922) mentioned the two islets, Rapa Iti (noting the presence of goats) and Tauturou (noting the presence of rabbits last recorded in 1988); however, he likely only visited Karapoo Koio (the only islet that he mentioned specifically). His colleague Beck (1921-22) visited and collected specimens on other islets without specifying their names (likely including Tarakoi). Few naturalists visited the islands during the 20th and early 21st centuries, until 2017, when the Société d'Ornithologie de Polynésie began eliminating invasive species from the islets for the conservation of seabirds and coastal vegetation (Table 2).

Modern data collection

Data were collected during visits to the islets by the authors between 1974 and 2024, as well as by analysing the field journals of WSSE collectors and the few publications dedicated to the birds of Rapa. Label information from preserved bird specimens deposited in museums also provided valuable information (including 183 petrel specimens held by American Museum of Natural History (AMNH), New York; Natural History Museum (BMNH), Tring, England; Leiden; Harvard; Yale Peabody; Smithsonian National Museum of Natural History (USNM) Washington; and Muséum national d'histoire naturelle (MNHN), Paris). Bird nomenclature follows the list compiled by Gill *et al*. (2024). Local bird names were recorded from community members during stays in Rapa. In recent surveys, bird numbers were estimated by counting individuals, nests with eggs, or chicks during daytime observations. The numbers of several petrel species were assessed by counting the number of nests or burrows within quadrats as follows: white-bellied storm-petrel nests in 3 quadrats of 728 m² on Tarakoi; black-winged petrel (*Pterodroma nigripennis*) burrows in 10 quadrats of 100 m² on Tauturou in 1989 and 1990; Murphy's petrel (*Pt. ultima*) in ten randomly selected quadrats, each covering an area of 400 m², on Tauturou in 2019. In areas of the quadrats where vegetation exceeded 1.5 m in height, the presence of petrels was checked using the "war-whoop" method (Tennyson & Taylor 1990). The Murphy's petrel population (and 95% confidence interval for the mean) on Tauturou was calculated based on the island's area of 20.09 ha minus 25% [an estimate of the area where the strawberry guava (*Psidium cattleyanum*) grove and the Pacific Island silvergrass (*Miscanthus floridulus*) are too dense for the Murphy's petrels]. Since 2019, burrow contents have been assessed using an endoscope (Bosch & Bluefire), automatic capture cameras (Reconyx), and SMA automatic audio recorders. Chick development was classified into three stages: 1 = Fully covered in down; 2 = Body covered in down, but feathers begin emerging on wings and tail; 3 = Mainly feathered, with some down remaining on various parts of the body, particularly the back and head.

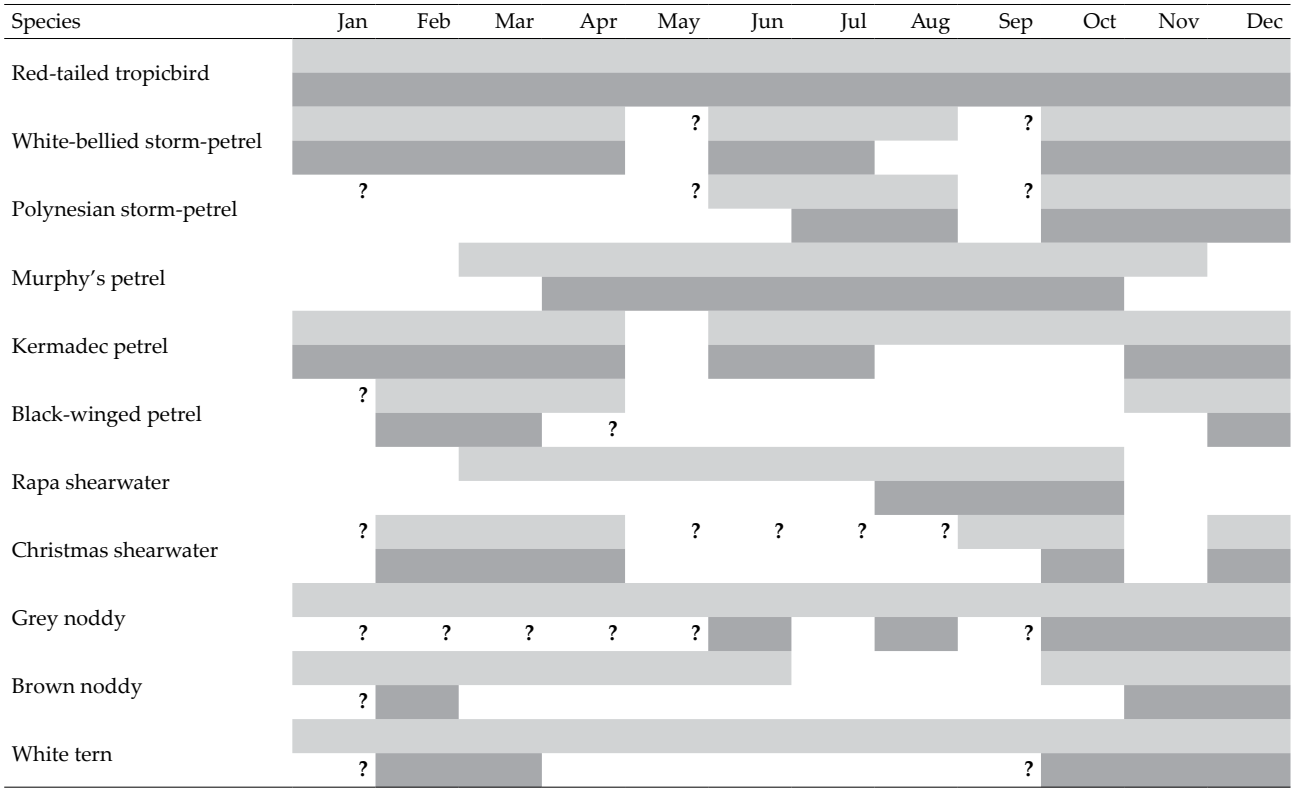
For each of the 12 breeding seabird species on Rapa, we first present the chronology and trends of the data, followed by the breeding periods, and finally, general remarks on their habitat. These observations are supplemented with data collected at sea off Rapa (Flood *et al.* 2021) and on the Morotiri Rocks (Gaskin 2007 and *pers. comm*. to J-CT 2006).

RESULTS

Red-tailed tropicbird (*Phaethon rubricauda*) tavake

Pre-European remains were found in archeological excavations on Rapa (Tennyson & Anderson 2012). **1921-1922**. Noted inland on Rapa as a breeder performing aerial displays (at least one group of 12–15 individuals), and breeder on Karapoo Koio (a large chick in a cave). **1974**. Nesting occurred on Rapa's coastal cliffs [Autea, Makatea (about 100 individuals), Rukuanga (about 100 individuals)], and inland in low numbers (Aurei: *c*. 50 individuals). Breeding sites on islets included on Karapoo Koio, Karapoo Rahi (several dozen pairs), Rapa Iti, Rarapai, Tarakoi, Tauturou. **1989-1990**. Breeding on Rapa, primarily on the large cliffs and in certain inland areas (Aurei, Ana Rua). Also bred on Tarakoi (8–15 pairs), Rarapai (5 pairs), Rapa Iti (5–10 pairs), Karapoo Koio (5–10 pairs), and Karapoo Rahi (10–30 pairs). The overall population was estimated at *c*. 1,000 pairs. **2017–2024**. Abundant in the cliffs of Rapa where several hundred breeders were recorded; also found on most islets (Karapoo Rahi, Karapoo Koio, Rapa Iti, Rarapai, Tapiko, Tarakoi, Tauturou); the largest colony is currently situated on Tauturou (100–500 pairs), with numbers elsewhere varying from several pairs to several

Table 3. Monthly calendar of breeding activities for seabirds on Rapa. Pale grey = adults present; dark grey = eggs and/or chicks recorded; **?** = insufficient data.



tens of pairs. The distribution has remained unchanged between 1974 and 2024; however, there are few census data.

Red-tailed tropicbirds breed year-round on Rapa, with no peak breeding season detected (Table 3). Nests were situated on ledges in cliffs, in caves, and in rock shelters.

White-bellied storm-petrel (*Fregetta grallaria titan*) kōru'e
This subspecies, endemic to Rapa and Morotiri, was described by Murphy (1928). It is larger than other *grallaria* subspecies, but is genetically closely related to other *grallaria* taxa (Cibois *et al*. 2015).

Pre-European bone remains were found in archeological excavations on Rapa (Tennyson & Anderson 2012). **1922**. Collected by the WSSE on Karapoo Koio: "*On the grassy slopes, mostly in the grass or in slightly excavated holes beneath clumps of grass or weeds, we found the petrel*, F. grallaria, *nesting in abundance*" (Quayle 1922). **1974**. Small breeding populations were recorded on Karapoo Koio, Rarapai, Tarakoi, and Rapa Iti (with only one occupied nest). Sites were shared with the Polynesian storm-petrel (*Nesofregetta fuliginosa*) on Rarapai and Tarakoi. **1989–1990**. Recorded on Karapoo Koio (observed during the day overflying the island), Rapa Iti (one observed in flight), Rarapai (both islets: 20 empty nests, 11 occupied nests), Tapiko (one pair, 13 empty nests), and Tarakoi (357 occupied nests; with 95% confidence limits of 288–412). **2017–2024**. Recorded on Karapoo Koio (exact number unknown), Rarapai (> 10 pairs), Tapiko (20–50 pairs), and Tarakoi (20–50 pairs). The birds were observed at various times during the night on Tauturou and Rapa Iti, but no nests were found. Breeding inland on Rapa is almost certain (although no nest found), since several tens of flying storm petrels were observed at night 9–10 Dec 2019, at an elevation of approximately 600 m, on the ridge between Mount Perau and Mount Karere. The population on the islets is fewer than 200 pairs; it remains unknown on Rapa. Maximum numbers seen at sea during chumming operations in Nov -Dec 2019 off Rapa were 120 on 12 November, 70 on 18 Nov, >100 on 3 December, and 60 off Morotiri on 24 November (Flood *et al.* 2021).

Individuals visit colonies every month of the year (Table 3). Laying typically begins in the second half of October; however, the influx to the colonies in November and December does not necessarily result in an increase in egg laying. Possible inter-annual variations are noted, such as in Feb 1922, when the WSSE mainly found nests with "*fresh*" eggs. A low number of chicks were found in the nests during each visit from March to July (two chicks were collected by WSSE in April). Number of breeding pairs (either with eggs or chicks) has remained very low, although the number of individuals visiting the islets can reach several hundred, especially in December. For instance, on the night of 24 Dec 1989, at around 7:00 PM, several hundred individuals were observed circling Tarakoi, with some displaying moulting of flight feathers. An hiatus at the colonies is noted during the southern winter, although some birds visit the islets at night (e.g., August 2019 when birds arrived in low numbers – a maximum of tens – at nightfall and left the island before sunrise). On Tarakoi in December 1989, the majority of nests were found under or against rocks (42 of 79), 24 were under grass, 9 were in small caves and 4 were without any protection.

Polynesian storm-petrel (*Nesofregetta fuliginosa*) kōru'e
Different populations vary significantly in colouration (Crossin 1974) and in size (Holyoak & Thibault 1984), with a cline from the largest individuals in Rapa to the smallest in the Marquesas islands. Only one plumage variant, the pale morph, was encountered on Rapa.

1921–1922. Not recorded by the WSSE, birds being probably absent at the time of their visit (February and April). **1974**. Breeders on Tarakoi, Rarapai, and possibly Karapoo Koio. **1989–1990**. Breeders observed on Rarapai

(25–99 pairs), Tarakoi (10–99 pairs), possibly Tapiko and Karapoo Koio (individuals observed in flight, but no nests found). **2002**. A partial census recorded 12 occupied nests on Tarakoi (B. Fontaine, *pers. comm*. to J-CT, 2002). **2017–2024**. Breeders observed on Rarapai and Tarakoi. Additionally observed on Tapiko on 2 Jun 2021, where an adult was found dead alongside a chick. Overall, the estimated number was less than 100 pairs. Breeding likely occurred on Morotiri with up to 5 birds seen between the rocks (Chris Gaskin, *pers. comm*. to J-CT, 2006). Maximum numbers seen at sea during chumming operations in Nov–Dec 2019 off Rapa were 240 on 12 Nov, and 30 off Morotiri on 24 Nov 2024 (Flood *et al.* 2021).

Birds were absent from colonies at least from February to April. Laying mainly occurs from July to December. In 1974, we noted eggs on 17 Oct, eggs and chicks at all stages on 7 Nov, although the number decreased on 6 Dec; in 1989, only chicks were present during the second half of December. Elsewhere, the breeding period is related to latitude; egg-laying is spread throughout all months near the equator in Line and Phoenix Islands (Crossin 1974), and Marquesas (Holyoak & Thibault 1984); it is seasonal and shorter on southern islands, such as Gambier (Lacan & Mougin 1974; Holyoak & Thibault 1984), and Rapa (Table 3). Nests were found from just a few metres above sea level to the top of the islets. They were positioned against rocks, within narrow cavities, and were always concealed by vegetation. However, often the tail and wings of the birds protruded into the open. Nests were composed of a few dry grasses or twigs. The nesting sites do not differ from those of the white-bellied storm-petrel.

Murphy's petrel (*Pterodroma ultima*) 'eūpo
1921-22. Two individuals collected by the WSSE on Rapa on 4 Apr 1921 were misidentified as *Pt. solandri* (Quayle 1921). During the second WSSE trip to Rapa 16–27 Feb 1922, they searched unsuccessfully for the "*blue shearwater*" or "*blue-faced shearwater*" [likely *Pt. ultima*] (Quayle 1922). During the same trip, 44 specimens were collected off Morotiri on 27 Feb 1922. **1974**. Visits were conducted at the end of the breeding season, coinciding with the departure of birds for migration. A few pairs and large chicks were observed on the following islets: Karapoo Koio, Rapa Iti, Tapiko, and Tauturou. **1989–1990**. Breeders on Rarapai (25–99 pairs), Tarakoi (10–99 pairs), perhaps Tapiko and Karapoo Koio (some seen in flight, but no count). **2017–2024**. The first comprehensive censuses were undertaken during 2019–2023, during the breeding period. The species breeds on islets but apparently not on Rapa itself. Breeding populations were observed on Karapoo Rahi (more than 40 pairs), Karapoo Koio (20–50 pairs), Rapa Iti (30–50 pairs), Rarapai (5–20 pairs), Tapiko (5–20 pairs), Tarakoi (*c*. 10 pairs), and Tauturou, which serves as the main breeding site. In August 2019, the population estimate for Tauturou was 2,863 ± 916 pairs. The estimate is derived from the number of active nests, including eggs, chicks, and juveniles, and therefore does not account for failed breeders. On Morotiri, several 100s of pairs were seen in September (Chris Gaskin, *pers. comm*. to J-CT, 2006), 1000s of birds were seen by G. Wragg in Apr-May 1999 (Anon. 2002); however, only a few birds were seen in November 1989 (Zimmer 1992) and 5-6 individuals in October & November 2019 (Flood *et al*. 2021).

Absent from breeding sites from November (last record on 6 December) to late February (first record on 16 March on Rapa islets). First eggs were laid at the beginning of April (Table 3). Nests were in the open in eroded areas, or hidden under ferns, guava trees, or among sparse *Miscanthus* grasses.

Kermadec petrel (*Pterodroma neglecta*) kea
Pre-European bone remains were found in archeological excavations on Rapa (Tennyson & Anderson 2012). **1921–1922**. Collected by the WSSE from the coastal cliffs of Rapa (Makatea) and on islets in April 1921 (10+) and February 1922 (30+). **1974**. Rapa: aerial displays of several dozens of birds observed (likely breeding) on the hills and cliffs of Makatea, Maurua, and Pukumaru. On the islets, found breeding on Tauturou and Karapoo Koio. **1989–1990**. Breeding mainly on islets, also on certain cliffs on Rapa (Makatea, Tevaiputa), and on rocky faces and slopes inland (Aurei, Pukumaru, Mauroa, Perau). Total population estimated at less than 1,000 pairs, with the main colony on Karapoo Rahi (100–500 pairs). **2002**. Up to five pairs displaying together by day on the crests of mounts Perau and Maugaoa (B. Fontaine, *pers. comm*. to J-CT, 2002). **2017–2024**. Breeding inland and on sea-cliffs of Rapa, but mainly on islets. Tauturou and Karapoo Koio were the main breeding sites and the total population was estimated at less than 1,000 pairs. On Tauturou 50–100 pairs were found in December 2019; however, 280 and 300 individuals were counted on 13-14 Mar 2019, and 100 chicks plus 60 incubating birds on 22 Mar 2021 (Withers *et al*. 2021). On Morotiri, suspected breeding on South and West rocks on 16 Dec 1991 (Seitre & Seitre 1991); only a single bird was seen during a landing on South-East Islet on 22 Sep 2006 (Chris Gaskin, *pers. comm*. to J-CT, 2006). Maximum numbers seen at sea during chumming operations in Nov-Dec 2019 off Rapa were 20 on 26 November as well as on 14 December, with 3–20 individuals seen daily (Flood *et al.* 2021).

On Tauturou, nests were on the ground beneath bushes, like Murphy's petrel's. Breeds year round: eggs and chicks recorded most months of the year, with peaks of presence in Nov-Dec, mainly with eggs (1989, 2019, and 2023); in January (1990) and February (1922) with eggs and chicks; and in Feb–Apr with older chicks (2019 & 2021). In Aug–Oct small numbers were noted, although one chick at stage 3 was recorded in August 2019. In addition, there are inter-annual differences in the breeding periods: during 27–29 Mar 2017, 100–200 individuals were observed; however, no eggs or chicks were seen (Butaud *et al*. 2018), while on 13 Mar 2019, on Tauturou, 280 individuals were counted, with 300 on 14 Mar, mainly with chicks in stages 1 and 2 (Table 3).

Black-winged petrel (*Pterodroma nigripennis*) tītī
Pre-European bone remains were found in archeological excavations on Rapa (Tennyson & Anderson 2012). **1921–1922**. Not noted by the WSSE in April 1921, and more intriguingly not noted in February 1922, during a period when the petrels should have been present on their breeding sites (15–25 February); however, it is uncertain whether Quayle landed on the main breeding sites (Rapa Iti, Tauturou); three specimens were collected at sea on 27 February off the Morotiri rocks, where the collectors could not land due to rough seas (Quayle 1922). The vernacular name in the Rapa language (tītī) was not noted by Quayle in his journal, nor recorded in April 1921 by the anthropologist Stokes (1955). The absence of any record on Rapa itself suggests that birds were not present at that time, since the WSSE members should have noticed their aerial display or presence at sea, as they did on Morotiri. **1974**. Breeding occurred on Rapa Iti and Tauturou. No counts were made; however, the birds were reoccupying sites left vacant by Rapa shearwaters. **1989**. A count conducted in December provided an estimate for the colony on Rapa Iti of *c*. 34–50 pairs, and 657 pairs on Tauturou (with 95% confidence limits ranging from 185 to 1645); the species

was not recorded on Karapoo Koio and Karapoo Rahi. On Tauturou, three sites with burrows occupied by petrels (either this species or Rapa shearwaters) were located: 1) at the top two-thirds of the slope facing Tapiko, 2) below the ridge facing south-southeast, and 3) in the center, facing north, below the ridge; the latter two sites had the largest number of burrows. On Rapa Iti, the burrows were located on the ridge and on the less steep eastern face. **2017–2024**. Found on three islets: Karapoo Koio (first and only record of some displaying birds on 4 Dec 2019), Rapa Iti, and Tauturou. Numbers seemed stable between 1974 and 2024; however, no count of occupied burrows was made during 2017–2024. The population, taking into account the number of displaying birds and frequented burrows, is estimated at *c*. 1,000 pairs. Maximum numbers seen at sea during chumming operations off Rapa in Nov-Dec 2019 were 35 on 26 November (Flood *et al.* 2021).

Highly seasonal. Arrival on breeding sites (Tauturou) recorded from 30 Oct (2024). Laying occurs in December (based on eggs found in burrows on 25 Dec 1989). The last records were on 30 Apr & 3 May 2020, by an automatic camera in front of a burrow on Tauturou (Table 3). The breeding phenology of the isolated population of black-winged petrel on Rapa is very similar to that recorded in Western Pacific waters (BirdLife Australia 2023a; Rayner *et al*. 2023). The same burrows are used successively by black-winged petrels and Rapa shearwaters. On Tauturou, most burrows were located under the grove of introduced strawberry guava at the summit of the islet (southern face), while others were dug directly into the ground, beneath rocks, or within shrubby vegetation. On Rapa Iti, the burrows were mainly in areas with soft soil covered by sparse vegetation, which has become increasingly rare due to overgrazing by goats. The burrows were up to a metre long, narrow, sometimes straight, more often with a bend; the nest was a chamber, lined with twigs and grass found nearby. Density of burrows is higher where the soil is soft.

Wedge-tailed shearwater (*Ardenna pacifica*)
Not recorded as a breeder before a single observation of a large chick in a burrow on Karapoo Koio on 3 Apr 2017. At sea, the species was often observed in Oct & Nov 2019, with up to 80 on 24 November, and 13–30 per day during chumming operations (Flood *et al*. 2021).

Christmas shearwater (*Puffinus nativitatis*)
1922. Several adults and one chick were collected by the WSSE on Karapoo Koio islet. **1974**. A bird incubating an egg in a rocky shelter on Karapoo Koio. **1989–1990**. Breeding on Tarakoi (5–10 pairs), Karapoo Koio (>100 pairs), Karapoo Rahi (>10 pairs) and perhaps a few pairs on Tauturou. **2017–2024**. Karapoo Koio (recorded in 2019, population size unknown); Karapoo Rahi (not recorded; however, the islet was rarely visited during the species' breeding period); Tarakoi (not recorded; a burrow found in July 2020 may have been of this species); one heard at Rapa Iti (2019); Tauturou (several breeders recorded in 2023). Population number probably less than 100 pairs, possibly declining. Maximum numbers seen at sea during chumming operations in Nov-Dec 2019 off Rapa were 150 on 3 December; 300 were seen in Morotiri on 24 November, and 100s were seen on the rocks in the evening on 23 November (Flood *et al.* 2021).

Little information is available on the timing of breeding. Probably a summer breeder on Rapa, with clutches observed as early as October and December (Table 3). Gaskin (2007) found adults incubating on Morotiri in late September 2006. The breeding period is also condensed in the Gambier Islands, with nesting beginning Sep–Nov, and juveniles fledging Feb–Mar (Lacan & Mougin 1974). Further north, Christmas shearwaters breed year-round on Kiritimati in the Line Islands (Schreiber & Ashmole 1970), and on Ra'ivavae Island in the Austral Islands, eggs were recorded in November and chicks in December (Bretagnolle *et al*. in press).

Rapa shearwater (*Puffinus myrtae*) kākikāki
Endemic to Rapa; probably breed also on Morotiri where data are restricted to birds seen at sea (Gaskin 2007).

Pre-European bone remains were found in archeological excavations on Rapa (Tennyson & Anderson 2012), although we cannot exclude that shearwaters were caught on the islets. **1921–1925**. Not collected by the WSSE in February or April; one collected by Kelsall (St. George Scientific Expedition) in April 1925. **1974**. Noted on the following islets: Karapoo Koio (a few pairs), Rapa Iti (three sites totaling around 60 pairs), and Tauturou (150–250 occupied burrows estimated). **1989**. No records were made because the visit was while the shearwaters were absent from breeding sites. **2017–2024**. Recorded on Karapoo Koio (at least 14 burrows), Karapoo Rahi (at least 5 burrows), Tauturou (less than 20 burrows), and Rapa Iti. On the latter islet in 2019–2024, endoscopic inspections of the 60 visible burrows revealed that no more than ten burrows were frequented by Rapa shearwaters, with fewer than 50 birds observed at the site (heard flying in the evening and morning). The total breeding population is less than 100 pairs.

Breeding is probably highly seasonal but there are few data (Table 3). The birds are absent from the colonies in December & January, probably departing in late October or early November [a single individual was seen at sea during chumming operations in Nov-Dec 2019 off Rapa (Flood *et al.* 2021)]. Breeders are present in March: an individual equipped with a GLS the previous year returned on 4 Mar 2020 (Jiguet *et al*. 2024). An image taken on 14 Mar 2019, and video recorded between 15 & 31 Mar 2017, showed two birds in flight and two on the ground (between 4:30 AM and 5:15 AM). A few data on incubation (in July) and chick rearing (from August to October) were obtained (Table 3). Habitat identical to that of black-winged petrel.

Grey noddy (*Anous albivittus*) pararaki
Pre-European bone remains were found in archeological excavations on Rapa (Tennyson & Anderson 2012). **1922**. Quayle (1922) reported isolated individuals and small flocks on Rapa. **1968**. Considered the most abundant of the three tern species, distributed in groups of two to three individuals on most cliffs of main island, with a high concentration on Karapoo Koio islet (Lacan ms). **1974**. Breeding occurred on the cliffs of Rapa, the islets Karapoo Koio and Karapoo Rahi (number unknown), Rapa Iti (several dozen pairs), Rarapai (less than 10 pairs), Tapiko (a few pairs), Tarakoi (several 100 pairs), and Tauturou (a few pairs). **1989-1990** & **2017–2024**. Breeding distribution and numbers are presented in Table 4. The total population was probably a few 100 pairs. In 2024, one year after rat eradication on Rapa Iti, nests with chicks and eggs were found in more easily reachable places, suggesting that predation pressure on the birds has decreased. Maximum numbers seen at sea during chumming operations in Nov-Dec 2019 off Rapa were several 100s on 12 November. There were up to 2000 on Morotiri on 23 & 24 November (Flood *et al.* 2021).

Grey noddies were present year-round on the shores of Rapa and its islets. Eggs and chicks were observed on all visits, with a peak of breeding activity in Oct–Nov (Table 3).

Table 4. Comparison of grey noddy populations on islets off Rapa between 1989 and 2017–2024. (X = 1–10, XX = 11–100, XXX = >100 pairs, and ? = present but number unknown).

Islets	1989	2017–2024
Karapoo Rahi	?	X
Rarapai	XX	X
Tapiko	?	X
Tauturou	XX	X
Karapoo Koio	XX	XX
Rapa Iti	XX	XX
Tarakoi	XXX	XXX
Aturapa		?

Brown noddy (*Anous stolidus*) goio

Pre-European bone remains were found in archeological excavations on Rapa (Tennyson & Anderson 2012). **1922**. Many eggs and chicks were observed on Karapoo Koio. (Quayle 1922). **1968**. Lacan (ms) reported breeding on two islets: Karapoo Koio and Rapa Iti, but without specifying any number. **1974**, **1989**, **2017–2024**. Breeding distribution and numbers on islets are presented in Table 5. Breeding observed in limited numbers on the cliffs of Rapa (Makatea, Iri) and mainly on the islets. No differences were observed in the sites occupied between the visits of 1974 and those of 2017–24. Most sites had colonies less than 100 pairs. Unfortunately, the main breeding site (Karapoo Koio) could not be surveyed during the breeding season from 2017 to 2024. Maximum numbers seen at sea during chumming operations during Nov-Dec 2019 off Rapa were 100s on 12 November; and several 100s off Morotiri on 23 & 24 November (Flood *et al.* 2021).

Table 5. Comparison of brown noddy populations between 1974, 1989 and 2017–2024 (X = 1–10, XX = 11–100, XXX = >100 pairs, and ?= present but number unknown).

Islets	1974	1989	2017–2024
Karapoo Rahi	?	XX	XX
Rarapai	?	XX	XX
Tapiko		XX	XX
Tarakoi	XXX	XX	XX
Tauturou	XX	XX	XX
Karapoo Koio	?	XXX	?
Rapa Iti	X	XX	XX

The breeding season for brown noddies was seasonal and condensed during the austral summer (Table 3).

White tern (*Gygis alba*) taketake

Pre-European bone remains were found in archeological excavations on Rapa (Tennyson & Anderson 2012). **1921–22**. The main information concerning this species found in Quayle's journal (16 Feb 1922, p. 304) concerns Rapa: "*The little white terns were rather plentiful above the timbered ravines*". They were also noted flying above a wooded slope of Rapa Iti (seen from a boat, p. 315). **1968**. The Karapoo Rahi forest appears to be the main site frequented by this tern. **1974**. Breeding observed on Rapa, on the rocky faces of Aurei (20–30 pairs). On the islets, nests were found on Tauturou (*c*. 100 pairs in the littoral grove), Karapoo Rahi (several dozen pairs in the grove), and Rapa Iti (15–20 pairs). **1989**, **2017–2024**. Breeding distribution and numbers on islets are presented in Table 6. Noted in the village of Aurei (20–30 pairs), and in very limited numbers in Rapa's forests, except in one locality (Ma'i'i) where it is relatively numerous (several tens of pairs), although in smaller numbers than the abundance observed by the WSSE in 1922. On Karapoo Rahi several 100 individuals in 1968, 1989, and 2002, but only about ten pairs in 2017–24 due to disappearance of the forest cover (see Discussion). Conversely, there is an increase on Rapa Iti, Karapoo Koio, and Tarakoi. The maximum number seen at sea during chumming operations in Nov-Dec 2019 off Rapa was 30 on 12 November (Flood *et al.* 2021).

Table 6. Comparison of white tern populations between 1989 and 2017–2024. (X = 1–10, XX = 11–100), XXX = >100 pairs, and ? = present but number unknown).

Islets	1989	2017–2024
Karapoo Rahi	XXX	X
Tauturou	XX	XX
Karapoo Koio		X
Rapa Iti	X	XX
Tarakoi		XX

White tern breeding is seasonal, occurring during the austral summer (Table 3), although one chick was recorded in April 1921. It breeds mainly in *Pandanus tectorius* trees and forests on islets and in ravines on the main island, but also directly on ledges in cliffs.

DISCUSSION

Trends over a century

The species list of breeding seabirds on Rapa has increased slightly over time, as the WSSE (Whitney South Sea Expedition) missed four species: Rapa shearwater (discovered in 1925), Polynesian storm-petrel and black-winged petrel (1974), and wedge-tailed shearwater (2017). Similarly, only the Christmas shearwater, Murphy's petrel, and Polynesian storm-petrel were absent from archaeological bone deposits (Tennyson & Anderson 2012).

The distribution and population size of a few species appear to have remained stable over the period considered (Table 7): red-tailed tropicbird, Murphy's petrel, and Kermadec petrel. Unfortunately, for storm-petrels, while their distribution has not changed since 1974, their numbers seem to have decreased. The abundance observed by Quayle in 1922 was not recorded a century later. Rapa shearwater is presumed extinct on Rapa's main island, although burrows of an unidentified seabird were found in 2019 at the top of a coastal cliff (Haiva Narii, *pers. comm.* to TW, 2019). On Rapa Iti and Tauturou, a sharp decline in the main populations of the Rapa shearwater occurred between 1974 and 2017–2024.

Black-winged petrels have possibly colonised (or recolonised) recently. Bones found in archaeological deposits indicate that the species was present before or during the early period of human settlement (Tennyson & Anderson 2012). However, it was not observed by the WSSE on Rapa in April 1921 or in February 1922 (although it was recorded offshore near Morotiri). In Eastern Polynesia, ancient extinctions of this species have been documented, notably in the Cook Islands, where this was attributed to Polynesian harvesting (Steadman 2006). We suggest that the species became extinct on Rapa and has recently recolonised the island, as it has done more recently on Rapa Nui (Barros & Schmitt 2013) and Ra'ivavae (Bretagnolle *et al*. in press). Since 1974, its distribution and likely its numbers have remained stable on Tauturou and Rapa Iti, and in 2019 it was observed on a third islet.

Table 7. Numbers and trends of breeding seabirds on Rapa and adjacent islets (2017–2024) expressed in breeding pairs. – = species not recorded, ? = present, but number unknown.

Species	Karapoo Koio	Karapoo Rahi	Rapa Iti	Rarapai	Tapiko	Tarakoi	Tauturou	Rapa	Total	Trend
Red-tailed tropicbird	5–10	25–50	25–50	5	?	8–15	100–500	?	*c.* 1000	stable
White-bellied storm-petrel	?	–	1+	30–50	20–50	350–500	–	100–500	500–1000+	probable decline
Polynesian storm-petrel	?	–	–	25–100	1+	11–100	–	–	250–500	probable decline
Murphy's petrel	20–50	50	30–50	5–20	5–20	10	3000–4000	–	4000–5000	probably stable
Kermadec petrel	11–100	100–500	1–10	–	–	–	250–500	100–250	1000	probably stable, or increase
Black-winged petrel	1+	–	200–500	–	–	–	200–500	–	1000	probably stable
Wedge-tailed shearwater	1+	–	–	–	–	–	–	–	–	unknown
Christmas shearwater	?	–	?	–	–	present	?	–	< 100?	possible decline
Rapa shearwater	15–20	5–10	< 10	–	–	–	< 20	–	< 100	sharp decline, at least since 1974
Grey noddy	11–100	1–10	40–50	10	10	200–500	5	?	1000–2000	possible decline
Brown noddy	?	11–100	25–50	11–100	11–100	11–100	11–100	?	500–1000	probable decline
White tern	1–10	25–50	15–25	–	–	11–100	100	50–100	250–500	probable decline

However, the absence of chicks in nests during surveys conducted between March and April from 2019 to 2023—despite fledging in New Zealand/Aotearoa occurring in early May (BirdLife Australia, 2023a)—suggests significant rat predation on chicks.

Discovery of a wedge-tailed shearwater pair breeding in 2017 extends its range in Eastern Polynesia nearly 500 km further south (Thibault & Cibois 2017), although it breeds at more southern latitudes in Australia and New Zealand (BirdLife Australia 2023b). Finally, a decline in white terns and brown noddies was observed on the islets.

Ecological segregation

The three tern species bred in wooded areas (brown noddy, white tern) and on cliffs (grey noddy, brown noddy, white tern). The two storm-petrel species occupied the same sites, with partially overlapping breeding periods. The two ground-nesting species, Murphy's and Kermadec petrels, shared the same islets. However, while Murphy's petrels were confined to the islets, Kermadec petrels also nested on coastal cliffs and in the interior of the main island. Both species had their highest populations on the same islet (Tauturou); however, their breeding seasons were complementary: Murphy's petrel bred from April to November, while Kermadec petrel bred predominantly from November to April.

The complementary use of the same sites was even more pronounced in the case of Rapa shearwater and black-winged petrel. These species shared the same burrows on the same islets, with black-winged petrels breeding from November to April and Rapa shearwater from April to October. On Lord Howe Island (Australia), Hutton & Priddel (2002) reported aggressive interactions between black-winged petrel and little shearwater (*Puffinus assimilis*) that used the same burrows at complementary breeding periods.

Invasive plants

The vegetation on the main island has declined significantly due to fires and grazing by cows, horses, and goats (Meyer 2011; Motley *et al*. 2014). The islets retaining the largest proportional cover of natural vegetation are the smallest ones, such as Tapiko and Tuamotu; these islets probably never supported goats. Other small islets, such as Rarapai and Karapoo Koio, are largely overrun by the invasive plant *Commelina diffusa*.

The islets that feature the largest areas of native habitats, such as semi-dry forests and cliff vegetation, are Karapoo Rahi, Tauturou, and Rapa Iti (Butaud *et al*. 2018). However, due to over-browsing by goats and possibly fires, Karapoo Rahi has lost most of its forest. A photograph from 1980 shows its western face almost entirely wooded from sea level to the summit, whereas by 2017 only a few pandanus plants remained (Paulay 1982; Butaud *et al*. 2018). On most islets, the introduction of goats resulted in the destruction and disappearance of forests. On Tarakoi, temporary cultivation (e.g., in 1993 by A. Guillemont) promoted the spread of invasive exotic plants (*Commelina diffusa*, *Melinis minutiflora*) and likely contributed to a decline in the populations of the two storm-petrel species.

Introduced mammals

Attacks by Pacific rats on Rapa shearwater chicks, as well as harassment of adults during incubation (recorded on camera traps), have been identified as the main causes of this species' decline. Whether such predation has occurred for centuries or is a recent phenomenon linked to the disappearance of forests on the islets remains unknown. Notably, invasive guava on Tauturou, which was rare in the 1970s–1980s, is now abundant. Its fruiting is highly

seasonal, potentially causing a spike in rat populations during the austral summer. Outside this season, however, rats may face food shortages and consequently prey on petrel chicks, as has been documented elsewhere (see Caut *et al*. 2008). In addition to reducing vegetation, goat trampling may also compact the soil, limiting the availability of soft ground necessary for burrow digging. Rapa shearwaters may also face threats from fisheries activities within their foraging or non-breeding ranges at sea (see Hatch *et al*. 2016 and Uhlmann 2003, for other seabird species). To investigate this possibility, 10 Rapa shearwaters were equipped with GLS dataloggers in August 2019. Although only one individual was successfully recaptured with its GLS functioning, the recorded foraging site was clearly outside major commercial fishing routes (Jiguet *et al*. 2024; P. Dufour, *pers. comm*. to VB, 2024). This suggests that land-based threats during the breeding season are the primary factors driving the decline of Rapa shearwater populations.

Conservation actions

Restoring island habitats and engaging local communities in conservation efforts are key elements to improve conservation and management of seabirds (Rodriguez *et al*. 2019). During the first assessment trip in 2017 by SOP-Manu, ship rats (*Rattus rattus*) were absent; however, three islets (Tauturou, Karapoo Rahi, and Rapa Iti) had feral goats and Polynesian rats (Butaud *et al*. 2018). Since then, SOP-Manu has partnered with Raumatariki, a local environmental NGO in Rapa, to advise and assist the Rapa community in restoring the uninhabited *motu* (islets in Polynesian) and protecting their unique assemblage of seabirds.

With the agreement of the "Tomite Rahi" (the council of elders Toohitu and the Rapa town hall), and the goat owners, and with the help of the local population, feral goats were removed from Tauturou and Karapoo Rahi in 2019, and from Rapa Iti in 2021. Rats were eradicated from Tauturou and Rapa Iti in Nov–Dec 2023 by a team from SOP-Manu, assisted by local volunteers and rope-climbing professionals.

Since 2017, but likely for much longer, storm-petrels, Rapa shearwaters, and even Murphy's and Kermadec petrels have been found grounded beneath public streetlights. Some of these birds were rescued, while others were likely taken by cats or dogs. Reducing the intensity of street lighting and turning it off during the middle of the night could help mitigate this cause of mortality.

Conclusion

This synthesis highlights significant gaps in knowledge, both temporally and geographically, particularly in Rapa's inland areas, where breeding sites and perhaps even new seabird species remain to be discovered. The seabird population of the Morotiri rocks has been insufficiently surveyed due to the challenges of landing there (Quayle 1922; *pers. obs*.), and very few naturalists have ever set foot on these rocks (Fosberg 1972; Gaskin 2007). The seabird assemblage on Morotiri appears similar to that of Rapa and its islets, with additional potential breeders such as sooty terns (*Onychoprion fuscatus*) (Thibault & Cibois 2017). The birds are safe from disturbance on these rocks; however, their total area is small, totaling less than 10 ha for the three main rocks. Nesting space for burrow-nesting species, such as Rapa shearwater and black-winged petrel, is likely limited by a scarcity of loose soil. Similarly, the number of storm-petrels may be constrained by the lack of ground vegetation under which they typically establish their nests.

ACKNOWLEDGEMENTS

The rat eradication project was funded by The David and Lucile Packard Foundation, BirdLife International, Life program of the European Union, and the Fonds Vert (France Nation Verte). Timi Peehi, Francky Faraire, Haiva Narii, Nathan Ye-On, Vehia Agnieray, Pamela Patira, Ravahere Taputuarai, and Albert Varney provided us with effective assistance in the field. The Tavana of Rapa, Tuanainai Narii, the municipal staff, and our partner, the Raumatariki association, particularly Poe Narii, provided us with invaluable logistical support. The entire population of Rapa supported our efforts. Alain Guillemont and Benoît Fontaine provided observations from 1993 and 2002 respectively, Vivien Gay assisted us with the surveys in Rapa Iti and Tauturou, Paul Dufour provided his analysis of the fisheries in southern Rapa, and Chris Gaskin kindly sent us his unpublished report on the seabirds of Morotiri. Christophe Brocherieux of the DIREN (local environmental authority) prepared the decree authorising the study (71 n°010978/MCE/ENV). We thank the bird staff in the natural history museums of AMNH New York, BMNH-Tring, Leiden, Harvard, Yale Peabody, USNM Washington, and MNHN Paris for their helpful assistance. Nicholas Carlile, Colin Miskelly, and James Russell enhanced the manuscript; we thank them for their very useful comments. To all of them, we extend our deepest thanks.

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