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SHORT NOTE

Does the New Zealand storm-petrel (*Pealeornis maoriana*) breed in northern New Zealand?

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Ever since the New Zealand storm-petrel (*Pealeornis maoriana*; hereafter NZSP) was rediscovered in 2003 (Flood 2003, Saville *et al*. 2003) there has been considerable speculation about likely breeding sites, ranging from the Hauraki Gulf to the tropical South Pacific. On 8 Jan 2011, during a seabird-watching trip in the Hauraki Gulf, one of several NZSPs was observed to have something attached to its right leg (seen at 36° 9.898'S, 174° 57.234'E, northwest of Little Barrier I/Hauturu). During several flybys, some at close range (to *c*. 3 m), NF took a number of images which showed a stalk of a plant attached to the bird's right tarsus (Fig. 1). Through binoculars the stalk could be seen to rotate at the point of attachment; this is confirmed by a sequence of photographs. The bird did not appear encumbered in any way by this object attached to its leg.

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The high resolution photographs enabled close study of both the 'stalk' and what was attaching it to the bird's tarsus. The mean tarsus length of NZSP is 35.6 mm (Stephenson *et al*. 2008; Gaskin, *unpubl. data*). The length of the stalk was estimated at *c.* 63 mm. NZSP take a B-size band, which is 2.8 mm in diameter, so the tarsus of NZSP would be *c.* 2-2.5 mm in diameter where the stalk was attached; we estimate the stalk's thickness at *c.* 1.2 mm. Both ends of the stalk appeared enlarged and to have broken off cleanly (Fig. 1). This suggests that it was either a petiole of a palmately compound leaf or a peduncle of a compound inflorescence/infructescence. The stalk was red-brown although at one end it appeared greenish.

All likely plant species considered were checked against herbarium material at the Auckland Museum (AK), and where possible wild material and cultivated material (at Oratia Native Plant Nursery) was also examined. By identifying the

Fig. 1. Image of the New Zealand storm-petrel with the stalk attached (Photo: Neil Fitzgerald).

species of plant attached to the storm-petrel's leg, we hoped to pinpoint the range of locations in which the bird could have picked up the plant and thus potential breeding sites of the birds.

POTENTIAL NEW ZEALAND CANDIDATES

1. *Pseudopanax lessonii* (houpara). Both the petiole and peduncle of this species are possibilities and vary in length from 40-160 mm and down to *c.*1 mm diameter (Fig. 2, 3). The swellings at both ends of the petioles and the peduncles were the best match for those in the photographs. Dead leaves, stalks and branches change colour and the red/green appearance in the photos matches a partially desiccated stalk of this species.
2. *Pseudopanax discolor*. The petiole of this species is also a possibility; they are slender, reddish and vary in length from 20-110 mm (Fig. 4).
3. *Pseudopanax gilliesii.* The appearance and dimensions of this plant's petioles makes this species another possibility. Petioles range from 20 to 120 mm (Fig. 5).

DISMISSED NEW ZEALAND CANDIDATES

1. *Pseudopanax arboreus.* Petioles are too long at >70 mm, the peduncles are the right length at 20-75 mm long, but too thick at >1.5 mm in diameter.
2. *Pseudopanax kermadecensis.* Petioles are too long at >70 mm, although the peduncles at 30-75 mm long by 1-2.5 mm in diameter means the thinner ones match on size. However, as with the very closely related *P. arboreus*, the peduncles of this species are homogenously dark red/brown and we have therefore ruled them out because the mystery stalk appears variable in colour and at the thin end of the size range (fresh material not available).
3. *Melicope ternata* (wharangi). Petioles of the compound leaves are too short and stout.
4. *Pisonia brunoniana* (parapara, bird-catching tree). The branches of the compound infructescences had a clean-swollen end; however the other end does not break off cleanly.

NON-NEW ZEALAND CANDIDATES

Outside New Zealand there appear to be many possible candidates and other species, especially members of the Araliaceae should be considered. In their world checklist of the Araliaceae, Frodin & Govaerts (2003) recognise only 7 species of *Pseudopanax* s.str. and 5 *Neopanax* (usually included in *Pseudopanax* s.lat. in New Zealand) – all are endemic to New Zealand. There are many close Araliaceae relatives outside New Zealand (*e.g., Polyscias),* where 116 species are recognised from Africa, Madagascar, Mascarene Is., S & SE Asia and Malesia to Micronesia, SE Polynesia and E Australia. Unfortunately, our access to material was limited to the New Zealand flora, although we suggest other reasons to support that it is most likely to be a New Zealand plant stalk.

The retained colour suggests the stalk is not very old and the colour is consistent with *Pseudopanax* petioles. While it is not possible to be certain without the actual specimen and DNA to provide confirmation, if the stalk became attached in the New Zealand area, the shape, the nature of the ends, the proportions (*i.e.,* length: thickness), and the colour of the stalk lead us to conclude that it was most likely a houpara petiole or peduncle, with 2 other *Pseudopanax* species (*P. discolor* and *P. gillesii*) as possibilities. *Pseudopanax* shed a substantial proportion of their petioles and peduncles naturally and cleanly, unlike other plants considered. Particularly with houpara,

Fig. 2. Houpara herbarium specimen showing petioles and peduncles (Photo: Ewen Cameron, Auckland Museum Herbarium, AK 141377).

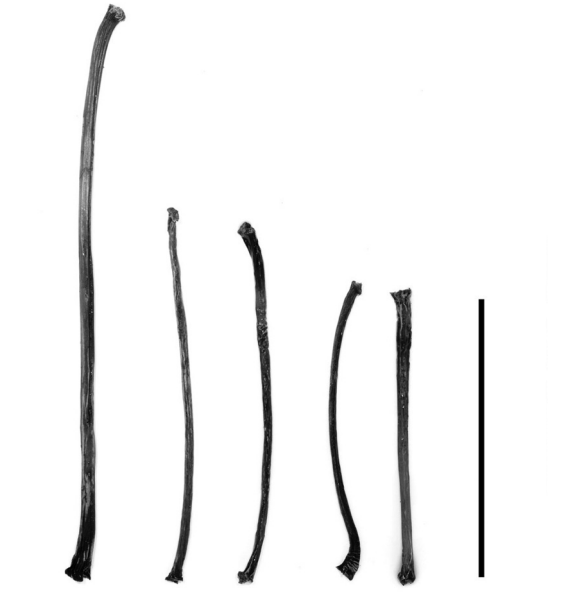

Fig. 3. A selection of houpara petioles and peduncles ex Ihumoana I, Bethell's Beach. Scale bar 50 mm (Photo: Neil Fitzgerald).

the petioles are extremely variable in size; these litter the ground in abundance where it is a prominent component of the coastal vegetation (*pers. obs*.).

What bound the stalk to the leg? The photographs indicate it was a filament of some kind wrapped around both the petiole and tarsus. It varied in appearance from a small open loop around both the tarsus and stalk (Fig. 6), or as one tight 'thread' around the leg, around the stalk and with a larger amount of the material in between. Trematode anklets have been observed on the legs of storm-petrels (Claugher 1976; Imber 1984), but both G. Taylor (*pers. comm*.) and M. Imber (*pers. comm*.) suggested that it is unlikely here, based not only on the appearance of the attachment but also the distance from the sub-tropical convergence zone where the trematode host euphausiids occur. A vegetative origin for the binding agent is also a possibility, such as a twisted or modified stem (*e.g.*, a tendril of mawhai; *Sicyos australis*) or a curled *Clematis* petiole. Vines such as native jasmine (*Parsonsia capsularis* and *P. heterophylla*) and bindweeds (*Calystegia sepium* subsp. *roseata* and *C. soldanella*) that grow amongst low scrub on coastal cliff faces and slopes were other possible contenders. However, no loose ends are evident in the photographs, as could be expected with modified stems.

A further possibility turned up in Jan 2011 on Burgess I, Mokohinau Is, when 'bands' or 'anklets' were found on the legs of 2 white-faced storm-petrels (*Pelagodroma marina*) during handling (Fig. 7). These tight bands on the tarsi were firm and rubbery and had to be cut off using scissors (K. Baird, S. Ismar & G. Taylor, *pers. comm*.). They appeared similar to the filament photographed by NF. The 2 samples under the microscope appeared scaly and fibrinogenous (S. Ismar, *pers. comm*.), which indicated sloughed skin. Sloughed skin has not been observed on the legs of the 12 NZSP specimens captured since 2003, or in fact on '1000s' of petrels handled by G. Taylor (*pers. comm*.), although it is possible that photos purportedly showing NZSP with bands are birds with this feature. In New Zealand, sloughed skin on legs is known only from rock wrens (*Xenicus giliventris*), an endemic alpine passerine (Warne & Morris 2009).

Did the stalk attach to the bird at sea or on land? We consider it highly unlikely that this occurred at sea. The odds of a NZSP sitting on the water and snaring a stalk floating in the ocean make it unlikely; whereas on land, storm-petrels walk or shuffle across the ground and under vegetation, or on mats of plants such as horokaka (*Disphyma australe*) or small-leaved pohuehue (*Muehlenbeckia complexa*). Their feet and legs come in contact with leaf litter under vegetation as they make their way to and from their burrows (Fig. 8). If a bird were to have a loop of *something* around its leg it would be possible for a petiole or other piece of vegetation to slip through the loop as the bird shuffled forward. Whatever the situation, it does seem as though this

bird had been on the ground in shrubby vegetation and as the stalk is most likely a houpara stalk, then that site is in northern New Zealand. The alternative scenario, that the stalk became attached on a tropical or sub-tropical South Pacific island, would have meant it remaining attached during an ocean crossing of >1,000 km. For a small seabird which is in frequent contact with the sea, and a journey that could take weeks, the relative freshness and rigidity of the stalk together with the loose nature of the binding agent make this seem unlikely.

Houpara is a common to locally abundant coastal species on offshore islands with a natural range limited to northern New Zealand (*i.e.,* Three Kings Is to Poverty Bay and northern Taranaki). However, as houpara and derivative cultivars, as well as hybrids with *Pseudopanax crassifolius* have been widely planted and are becoming naturalised in many regions south of their natural distribution, including Wellington (Perrie & Shepherd 2009), we cannot rule out an area further south. The other 2 possible contenders are: (1) *P. discolor*, which has a much more restricted range, between 36° 11′ (Cameron 2005) and 37°S (Allan 1961), from Great and Little Barrier Is to the upper Waikato region including the Coromandel. This species is naturally rare on islands, found only on the larger Barrier Is. It ranges from sea level to around 750 m, and is locally common in shrubland and forest. (2) *P. gilliesii* is known only from eastern Northland (northern side of Whangaroa Harbour and locally in Puketi Forest) in coastal or lowland hardwood forest and shrubland (an earlier Little Barrier record was in error; de Lange *et al.* 2004). The morphology and coastal habitat of *Pseudopanax gilliesii* is similar to *P. lessonii* with which it often coexists.

The known range of the NZSP is currently restricted to an area from north of North Cape to eastern Coromandel with most sightings occurring in the Hauraki Gulf from the beginning of Sep to the beginning of Jun (Gaskin & Baird 2005; CG *unpubl.*), reflecting search-effort to some extent. The exceptions to this are: 3 sightings off New Caledonia (Apr 2008, 2010, 2011) which were considered to be young NZSP (M. Imber, *pers. comm.*), although some observers regard these to be possibly a larger taxon related to NZSP (Howell & Collins 2008; C. Collins, *pers. comm.*); 2 birds seen off NSW, Australia (Mar and Apr 2010) (N. Haas & R. Stephenson, *pers. comm.*); and 1 bird off Southport, Queensland, Australia (Jun 2011) (R. Morris & P. Walbridge, *pers. comm.*). Two of the Australian birds were exhibiting signs of moult.

Despite these sightings outside New Zealand waters, NZSP occurs in the Hauraki Gulf at least 8 months of each year (Gaskin & Baird 2005; CG, *unpubl. data*), during a period of considerable change in environmental conditions. For example, sea sur-

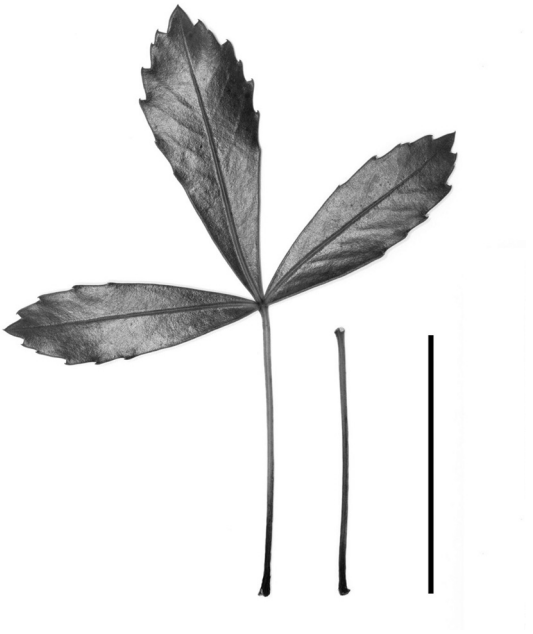

Fig. 4. Petiole and leaves of *Pseudopanax discolor* ex Oratia Native Plant Nursery. Scale bar 50 mm (Photo: Neil Fitzgerald).

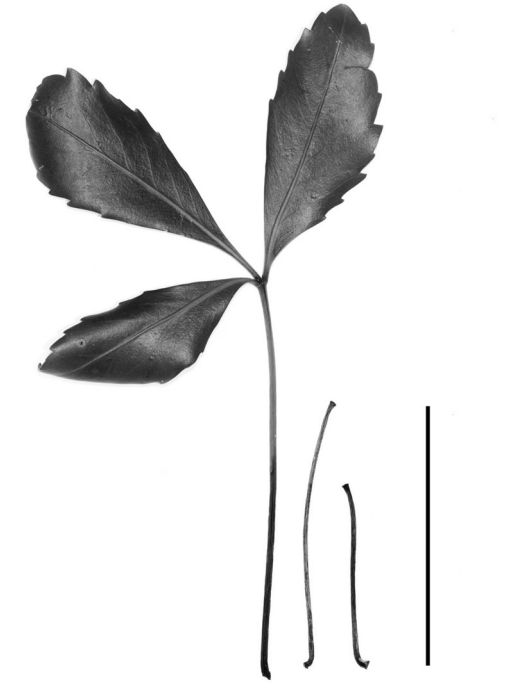

Fig. 5. Petiole and leaves of *Pseudopanax gilliesii* ex Oratia Native Plant Nursery. Scale bar 50 mm (Photo: Neil Fitzgerald).

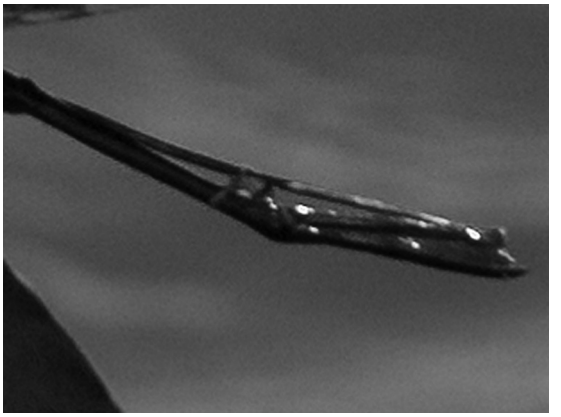

Fig. 6. This detail shows the 'binding agent' and the relatively loose loop allowing the stalk to rotate (Photo: Neil Fitzgerald).

Fig. 8. White-faced storm-petrel on the ground, Burgess I, Mokohinau Group (Photo: Adrien Lambrechts).

Fig. 7. Photo of possible sloughed skin on tarsus of white-faced storm-petrel, Jan 2011, Burgess I, Mokohinau Group (Photo: Karen Baird).

face temperature (SST) records for the Hauraki Gulf (as measured at Leigh Marine Laboratory) range between 13.5°C and 21.3°C, for Oct 2009 and Feb 2009, respectively (data supplied by J. Aitken and J. Evans, University of Auckland). Since 2003, when NZSP was 'rediscovered', the Gulf and New Zealand waters generally have experienced El Nino (2004-2005, 2006-2007, 2009-2010) and La Nina (2007-2008, 2010-2011) events (*http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml*), each of which can have a major influence over seabird distribution (G. Taylor, *pers. comm*.). Were NZSP breeding elsewhere, as has been suggested by Onley & Scofield (2008), a more variable pattern of occurrence for the Hauraki Gulf could be expected. On the contrary, NZSP, while not exactly sedentary from current data, exhibits a strong fidelity to the Hauraki Gulf, a pattern similar to known Gulf-breeding procellariiforms. For example, fluttering shearwater (*Puffinus gavia*), northern little shearwater (*P. assimilis haurakiensis*) and common diving petrel (*Pelacanoides urinatrix*), are either mostly sedentary, or disperse for limited periods (up to 4 months) away from Gulf waters. This behaviour contrasts markedly with taxa that breed outside the region (*e.g.,* Wilson's storm-petrel, *Oceanites oceanicus*; grey-backed storm-petrel; *Garrodia nereis*) where occurrence within the Gulf is haphazard, and if seen are generally either side of their known breeding period. In addition, there are no records of NZSP in the Hauraki Gulf or in northern New Zealand waters exhibiting signs of intense moult. Given that storm-petrels >1 year old generally moult after breeding (Warham 1996), NZSP, at least any breeding in northern New Zealand, could achieve this during austral-autumn and -winter months. Signs of moult on 2 NZSP seen (and photographed) off the eastern Australian coast in Apr 2010 and Jun 2011 appear to confirm this view. The alternative scenario would be that all NZSP seen in northern New Zealand waters are 1st-year birds, and that NZSP breed elsewhere. NF's photographs of the NZSP show some feather wear on the upper wing coverts, tips of the primaries and some of the feathers on the tail which could be attributed to wear associated with the bird having been on land. The different generation central tail feathers would indicate this bird is either a sub-adult or adult bird. The timing of this record supports the view that NZSP is a summer breeder, although it does not narrow it down to either spring-summer or summer-autumn breeding.

The extreme vulnerability of storm-petrels to predation (Taylor 2000a) is another factor that will determine where these birds might be breeding. The site where the stalk became attached to this bird is most likely to be on a rat-free island, an island that has always been rat-free or one that has become rat-free following eradication (Table 1). It should be

Table 1. Rat-free islands in northern New Zealand where houpara occurs and/or islands where storm-petrels are known to be breeding in the region (* denotes botanical surveys which cover one or more islands listed on separate lines, the reference follows the last entry; WFSP = white-faced storm petrel).

Island group	Island	Houpara occurrence	Notes
Three Kings Is	Great /Manawa Tawhi	Grazed to extinction by goats (Bellingham *et al.* 2010)	Believed always rat-free; goats introduced to Great I in 1889 & eradicated in 1946 (Turbott 1948)
	South West	Present (1982, AK herbarium)	WFSP not known to breed
	West	Present (2003, AK herbarium)	
	North East	Not present (Baylis 1948)	
Motuopao I	Motuopao	Not present (Forester 1993)	Rat-free from 1992 (McKenzie 1993), though WFSP known to co-exist with rats (Taylor 2000b)
Moturoa Is	Moturoa	Rare (Wright 1977a)	All islands in group believed to have been rat-free (Wright 1977b)
	Green	Not present*	
	Sugarloaf	Not present*	
	Whale	Not present*	WFSP breeding on Whale Is, and 'probably breeding' on other islands (Adams 1971)
Cavalli Is	Cavalli	Present 19/29 islands (Wright 1979a,b)	Most islands apparently rat-free (Hitchmough 1979). WFSP recorded on Haumaruru (Sibson 1953)
Motukokako/ Piercy I	Motukokako	Frequent (Cameron & Taylor 1991)	Believed always been rat-free (Atkinson 1986). WFSP not recorded breeding
Poor Knights Is	Tawhiti Rahi	Present (Campbell & Atkinson 2002)	All islands of the group believed always rat-free (Hayward 1993)
	Aorangi	Common (de Lange & Cameron 1999)	Small numbers of WFSP breed on Aorangi (S. *Bartle pers. comm.*; Taylor 2000b)
	Aorangaia	Locally common (EC *pers. ob.*)	
	Archway	Unknown but likely present	
Marotere Is/Hen & Chickens Is	Lady Alice/Mauimua	Frequent (Cameron 1984)	The 3 main Chickens rat-free since 1994-1997 (Towns & Parrish 2003)
	Whatapuke/Mauiroto	Common*	WFSP not known to breed in group
	Coppermine/Mauipae	Common*	
	Northwestern Chicken/ Muriwhenua/Wareware	Present (Atkinson 1971)	Northwestern Chicken believed always rat-free (Atkinson 1971)
	Sail Rock	Absent (Atkinson 1972)	Sail Rock believed always rat-free (Whitaker 1973)
	Hen /Taranga	Common (Wright 1978)	Rats (kiore) still present
Mokohinau Is	Burgess	Rare (Cameron 1990a)	Rat-free since 1990 (McFadden & Greene 1994). WFSP confirmed breeding on Burgess I only
	Flax/Hokoromea	Localised*	Rat-free 1991 (McFadden & Greene 1994)
	Atihau/Trig	Rare*	Rat-free 1991 (McFadden & Greene 1994)
	Lizard	Not present	Former breeding colony of WFSP (McCallum 1986) appears extirpated (CG *pers. ob.* Oct 2010)
	Fanal	Locally abundant (Wright 1980; de Lange *et al.* 1995)	Rat-free since 1997 (Veitch 2002)
Little Barrier I/ Hauturu	Little Barrier	Common in coastal forest (M. Young *pers. comm.*)	Rat-free since 2006. WFSP not known to breed
The Noises	Motuhoropapa	Abundant (Cameron 1998)	Rat-free mid 1980s (Moors 1985); subsequent incursions, rat-free 2002 (Clout & Russell 2006)
	Otata	Abundant*	Rat-free since 2002 (Clout & Russell 2006)

Table 1. Continued.

Island group	Island	Houpara occurrence	Notes
	Maria	Present (SHD *pers. ob.*, 2010)	Rat-free since 1964 (Moors 1985)
	David Rocks	Common (EC *pers. ob.*)	Rat-free since 1964 (Moors 1985)
Channel I	Channel	Present (AK Herbarium)	Rat-free (Taylor 1989). WFSP not known to breed
Western Coromandel Is	Motuokino	Present (Esler 1978)	Rat-free (Taylor 1989, R. Chappell *pers. comm.*). WFSP formerly present (Taylor 2000b), no sign in recent years (R. Chappell *pers. comm.*)
	Cow	Present (Esler 1978)	Rat-free (Taylor 1989, R. Chappell *pers. comm.*). WFSP formerly present (Taylor 2000b), no sign in recent years (R. Chappell *pers. comm.*)
Cuvier I/Repanga	Cuvier	Common (Beever *et al*. 1969; Wright 1981). More abundant following rat eradication (R. Chappell *pers. comm.*)	Rat-free since 1993 (Towns *et al*. 1995). WFSP not known to be breeding
Mercury Is	Middle	Abundant (Cameron 1990b)	Believed always rat-free (Whitaker 1973)
	Green	Few (Atkinson 1964)	Believed always rat-free (Whitaker 1973)
	Korapuki	Present (Towns & Atkinson 2004)	Rat-free 1987 (McFadden & Towns 1991)
	Stanley/Atiu	Scare (Taylor & Lovegrove 1997)	Rat-free 1992 (Towns *et al*. 1993)
	Red Mercury /Whakau	Rare (Lynch *et al*. 1972)	Rat-free 1994 (Towns *et al*. 1994)
	Double/Moturehu	Present (Towns 2009)	Rat-free since 1989 (McFadden 1992). WFSP not known to breed in Mercury Group
Ohena Sub Group of Mercury Group	Ohinau	Becoming more common since rodent free (R. Chappell *pers. comm.)*	Ohinau rat-free since 2005 (Hoare *et al*. 2007). WFSP found breeding on Ohinau in 2002 (R. Chappell *pers. comm.*)
	Ohinauiti	Reasonably common (R. Chappell *pers. comm.*)	Ohinauiti believed to have always been rat-free. WFSP reported breeding (Taylor 2000b; Mulder *et al*. 2009)
Alderman Is/ Raumaahua	Ruamahuanui	Not present (Court *et al*. 1973)	Believed always been rat-free (Whitaker 1973)
	Middle Chain	Localised*	Middle Chain rat-free since 1994 (Thorpe 1997)
	Raumahuaiti	Localised*	Believed always been rat-free (Whitaker 1973)
	Hongiora	Localised*	Believed always been rat-free (Whitaker 1973). WFSP breed on Hongiora in large numbers (Fogarty & Douglas 1973; Taylor 2000b)
Nga Motu/ Sugarloaf Is	Motumahanga/ Saddleback	Present (G. Taylor *pers. comm.*)	Rat-free. WFSP breeding (G. Taylor *pers. comm.*)

noted that houpara is not on all rat-free islands (it is not present on Stack H, Groper and Lizard Is in the Mokohinau Group, for example).

In conclusion, the probable identity of the stalk, combined with the at-sea sightings, timing of moult and environmental data strongly suggests NZSP to be breeding somewhere in northern New Zealand; most likely on a rat-free island in the wider Hauraki Gulf region and during either the austral spring-summer or summer-autumn. The localities listed in Table 1 are a starting point for further investigation. It needs to be emphasised that this account relates to 1 bird only and that the nesting of the NZSP is not necessarily limited to being close to or under houpara. Finding the breeding site(s) of NZSP remains of paramount importance to determine population size, seasonal activity and to identify threats and implement appropriate conservation management for the future protection of this species.

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