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Results of Banding White-faced Storm-Petrels, *Pelagodroma marina* at Mud Islands, Victoria

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White-faced Storm-Petrels *Pelagodroma marina* were banded almost annually at Mud Islands between 1955 and 1980. Bands were applied to fledglings removed from burrows and to free-flying birds captured in mist nets. Two percent of the 12 652 banded birds have been recovered, mostly at Mud Islands during subsequent breeding seasons. Recoveries were heavily biased by the type of bands used; aluminium bands lasted only 3 or 4 years. Half the known-age birds recovered have been found dead or dying around Port Phillip Bay within 4 weeks of their presumed fledging dates. The oldest known-age bird was 16 years when last recaptured. Almost all recoveries of birds banded when free-flying were from Mud Islands in subsequent breeding seasons. The few long-distance recoveries are considered in relation to the supposed migratory routes and low probability of recovering banded storm-petrels. Pre-breeding birds probably first return to their natal colony at 3 years old and probably return annually thereafter, although some birds have been recovered from the nearby South Channel Island colony.

White-faced Storm-Petrels *Pelagodroma marina* have been known to breed at Mud Islands, Port Phillip Bay, since 1882 (Campbell 1900). The colony was once apparently more extensive than the present 5 600 burrows (95% confidence limits 4 400-6 900) (Harris and Norman 1981) although estimates of the numbers of Storm-Petrels breeding there suggest that there has been little change since 1966 (Table 1).

Aspects of the ecology and geomorphology of Mud Islands are described by Keble (1947), Willis (1947), Gillham and Thomson (1961), Pescott (1970) and Bird (1973). The preferred breeding habitats of White-faced Storm-Petrels at Mud Islands are described by Gillham and Thomson (1961), Harris (1979) and Harris and Norman (1981).

Few details are available of the breeding biology of the White-faced Storm-Petrel in southern Australia. The breeding season is protracted and non-synchronous (Jones 1937, Richdale 1965). Birds usually return to colonies in September or October when burrows are cleaned-out and a single egg is laid in late October or November. Incubation is shared by both parents in shifts lasting 4 to 6 days (Richdale 1965, Brothers 1981) and, in a New Zealand colony, the incubation period is about 56 days (Richdale 1965). Both parents feed the young, probably once per night, and it is abandoned shortly before fledging 52-67 days after hatching (Richdale 1965). A high percentage of pairs apparently stay together and use the same burrow in successive years (Richdale 1965, Serventy *et al.* 1971) although site tenacity was lower at a newly established colony in Bass Strait (Brothers

TABLE 1

Estimates of numbers of White-faced Storm-Petrels or their burrows on Mud Islands.

Year	Numbers and comments	Source
1903	5 000 pairs; rookeries once far more extensive	Townsend (1903)
1906	5 000 burrows	Campbell (1933)
?	Hundreds of tons of sand and soil constituting the main petrel rookery have been removed, and the birds had to build their burrows among the tree roots	Chief Inspector of Fisheries and Game, in Gillham and Thomson (1961)
1928	22 000 burrows	A. G. Campbell cited in Gillham and Thomson (1961)
1953	The colony had further increased	Tarr (1954)
1956	8 000–10 000 pairs	Wheeler, in Gillham and Thomson (1961)
1959	10 000 burrows	Wheeler (1959)
1964	Botswain Island colonies (once estimated at 5 000 burrows) almost completely destroyed by high tides. Population of East Island was perhaps only half its previous size (5 000 burrows). Total population was probably 3 000–4 000 burrows	Wheeler (1964)
1966	2 500 pairs occupying 5 000–6 000 burrows. On the "Airstrip" there were 4 200 burrows of which 2 180 were probably in use. On Western Island the 300 burrows were not in use. On Botswain Island only half the 400 burrows were in use	Pescott (1966)
1970	3 000 pairs	Pescott (1970)
1973	May be recolonising the north end	Anon (1974)
1978	The north end of the island was being recolonised. About 6 000 birds present	Gaynor (1978)
1978	5 600 ± 1 200 burrows in "Airstrip" colony. 198 burrows in Botswain Island colony	Harris (1979)

1981). At Mud Islands young usually fledge between late January and late February which is earlier than the fledging dates at Whero Island, New Zealand (Richdale 1965).

There is a long history of banding of White-faced Storm-Petrels at Mud Islands; between 1914 and 1919 members of the Bird Observers Club (BOC) used home-made aluminium bands on storm-petrels taken from burrows (Chandler 1959), and in December 1931, 50 storm-petrels were banded with aluminium quail bands provided by the Victorian Fisheries and Game Department (Campbell 1933). The Altona Survey Group began annual banding trips to Mud Islands specifically to band the storm-petrels in January 1955 (Wheeler 1981). In 1962 the newly-formed Victorian Ornithological Research Group (VORG) assumed responsibility for the banding and for the next 15 years banding was carried out by members of VORG, BOC and the Geelong Field Naturalists Club (GFNC). Between 1977 and 1980 the banding was organised by GFNC and it ceased in 1980 because the

project was yielding little new information. Here we analyse banding and recovery data collected between 1955 and 1980.

Methods

Banding* of White-faced Storm-Petrels took place mainly at the 'Airstrip' colony on Mud Islands during a three-day visit in late January of most years between 1955 and 1980 (Table 2). The 'Airstrip' is a long narrow dune running north-south between the central lagoon and Eastern Island at the north-east of the island system. Storm-petrels were captured either by removing nestlings or adults from burrows during daylight, or by capturing adults in mist nets as they returned to the colony after dark. Because the original aim of the study was to determine seasonal movements, captured birds

* Bands used were supplied by the Australian Bird-Banding Scheme, Division of Wildlife and Rangelands Research, CSIRO.

TABLE 2
Numbers of White-faced Storm-Petrels banded on Mud Islands, 1955–1980.

Year	Nestlings	Adults in burrows	Mist-netted Free-flying birds	Total
1955	17		1	18
1957	167	2	1	170
1958	938	28	42	1 008
*1959	991	20	31	1 042
1960	1 314	1	12	1 327
*1961	945	15	4	964
1962	840	9	22	871
1963	659	24	426	1 109
*1964	480	11	236	727
1965	681	7	1 005	1 693
1968	230		367	597
1970	203	9	432	644
*1972	293		38	331
1973			103	103
1974	100		618	718
1976	321		115	436
1977			590	590
1978	33	2	5	40
1979	20		89	109
1980			155	155
Grand totals	8 232 (65%)	128 (1%)	4 292 (34%)	12 652

* years when a full moon corresponded with the banding

were quickly banded and then released; usually no attempt was made to determine breeding status, age, sex weight or morphometrics.

Bands were made of aluminium, monel or stainless steel. During the early years of the study only aluminium bands were used but their use was discontinued in 1962 when monel bands became available. Surprisingly, some aluminium bands were used in five subsequent years (Tables 5 and 7). Stainless steel bands were used in 1977 and thereafter.

Between 1955 and 1962 most birds were taken from burrows although small numbers were captured in mist nets in 1958 and 1959 (Table 2). Mist netting gradually became the dominant method after 1963 and removal of birds from burrows ceased after 1979 due to concern that excessive damage to burrows was occurring. After 1963, between three and six mist nets were set along the western side of the 'Airstrip' colony

between dusk and about 01:00 hours on two consecutive nights of each yearly visit.

The mist-netted birds would have included an unknown proportion of pre-breeders. Richdale (1965) found that 30% of captured White-faced Storm-Petrels from Whero Island, New Zealand, were pre-breeders. In this study pre-breeders were not recognized, so all free-flying birds have been combined with the adults removed from burrows (which may also have included some pre-breeders, Richdale 1965) and termed adults in the following analyses. We have assumed that comparable samples at a similar late stage of the breeding cycle were obtained in each year. However, sample size varied between years depending on the number of nets used. Additionally, the numbers of adults returning to the colony was reduced during periods of full moon and catch rates in mist nets were probably also influenced by wind speed.

Results

Numbers Banded

Between 1955 and 1980, 12 652 White-faced Storm-Petrels are known to have been banded at Mud Islands. In addition, some storm-petrels were banded with monel bands purchased in 1961 by the BOC. As documentation of this latter banding was somewhat inadequate, there is an unknown number of banded birds in the population for which banding details are unavailable (D. Purchase pers. comm.). A small number of such birds has been recovered on Mud Islands.

The numbers of nestlings, free-flying birds and presumed breeding adults (those removed from burrows) banded in each year are shown in Table 2. Sixty-five per cent of the birds were

banded as nestlings and are therefore of known-age, 1% were adults removed from burrows and 34% were free-flying birds captured in mist nets.

Activity at breeding colonies fluctuates with the phase of the moon and fewer birds come ashore on bright nights although breeders still tend chicks (Richdale 1965, T. Pescott and G. Gaynor pers. obs.). The smaller catches of adults achieved on three of the four occasions when banding coincided with a full moon (Table 2) may have been largely due to this affect. In 1963 the number of storm-petrels breeding at Mud Islands was reduced by the destruction of the Botswain Island colony by high tides (Wheeler 1964). This probably also reduced the number of birds captured during the 1964 visit.

Overall Recoveries of Banded Birds

Only 256 (2%) of the 12 652 banded birds have been recovered, most at Mud Islands in subsequent breeding seasons (Table 3). Of the 8 232 nestlings banded, 84 (1%) have been recovered and slightly less than half of these were recovered at Mud Islands — of these, only one has been recaptured more than once. Of the 4 420 adults banded, 172 (4%) have been recovered, almost all at Mud Islands — of these, only three have been recaptured more than once.

Recovery rates were biased by the type of bands used in each year; aluminium bands lasted only three to four years, presumably due to corrosion by salt water and abrasion, particularly while burrowing. Consequently, re-

TABLE 3

Recoveries of White-faced Storm-Petrels banded at Mud Islands.

	Nestlings	Adults	Total
Numbers banded	8 232	4 420	12 652
No. recovered at banding site	40	165	205 (1.6%)
No. recovered elsewhere	44	7	51 (0.4%)
No. recovered more than once	1	3	4
Totals (excluding second recoveries of any individuals)	84 (1%)	172 (4%)	256 (2%)

TABLE 4

Comparative longevity of aluminium vs. monel and stainless steel bands as measured by numbers of White-faced Storm-Petrels with each band type recovered in the years after banding.

Band type	Number used	Recoveries in years after banding																	Total recovered (%)
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	
Aluminium	5 738	21	12	7	2	0	0	1	0	0	0	0	0	0	0	0	0	0	43 (0.7)
Monel and Stainless Steel	6 914	46	34	32	10	23	12	5	11	12	8	4	8	3	0	2	2	1	213 (3.1)
Totals	12 652	67	46	39	12	23	12	6	11	12	8	4	8	3	0	2	2	1	256

coveries of aluminium bands have been few and short-term compared with recoveries of monel and stainless steel bands (Table 4). It is likely that many aluminium bands placed on nestlings were lost before the birds returned to Mud Islands to breed. Several bands were almost illegible, or crumbled when handled, following recapture of the birds two or three years after banding. These variable rates of band loss, uneven sample sizes between years, and low recovery rates preclude the calculation of survival rates or population estimates.

Recoveries of Known-age Birds

The spread of recoveries of known-age birds across the years after banding (Table 5) indicates that half the recoveries were of first year birds. The remaining recoveries were evenly spread across the years suggesting a high adult survival rate. The oldest known bird was 16 years old when last recaptured. Few recoveries have come from birds banded before 1962 when only aluminium bands were available.

The youngest known-age birds recovered back at Mud Islands were in their third year (4 of 40 recaptures) suggesting that birds do not return to the colonies until then. As the reproductive

condition of captured birds was usually not assessed, no known-age birds were later found to be breeding.

Almost all the known-age birds recovered away from Mud Islands were recovered during their first year and 30 (81%) were recovered during February of their first year, that is, within four weeks of the presumed fledging date (Table 6). Most recoveries of first year birds occurred on beaches of Port Phillip Bay or in bayside suburbs. Recoveries were evenly spread in all directions around Mud Islands and came from up to 50 km away at the northern end of the Bay. Recoveries of older known-age birds were few (Table 6) and mainly came from Mud Islands or the nearby South Channel Island where some storm-petrels can become trapped and die in old cannon emplacements (Wheeler 1975). One known-age bird was recovered on a ship near Cape Otway, 130 km south-west of Mud Islands in November of its second year. Another was captured alive on a ship 65 km north-west of Geraldton, Western Australia on 5 June 1961. As the finder of this bird neglected to record one digit of the band number, this recovery has not been accepted as a confirmed recovery by the Australian Bird-Banding Scheme (D. Purchase pers. comm.). However, our

TABLE 5

Recoveries in years after banding of White-faced Storm-Petrels banded as nestlings at Mud Islands.

Year	No. banded	%AL. bands	Recoveries in years after banding																Total recovered	
			0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16		16-17
1955	17	100																		0
1957	167	100																		0
1958	938	100	3	1																4
1959	991	100	4			1														5
1960	1 314	100	6		2															8
1961	945	100	5		1				1											7
1962	840	0	7			2	1							2					1	13
1963	659	0		1				2				1					1			5
1964	480	0	4				3					3			1					11
1965	681	0	5		1			1			3		2	1	1		1	2		17
1968	230	0	2							1				1						4
1970	203	0			1															1
1972	293	26	2					1		1										4
1974	100	100	1																	1
1976	321	0	1				1													2
1978	33	0			2															2
1979	20	0																		0
Totals	8 232		40	2	7	3	5	4	1	2	3	4	3	3	2	0	2	2	1	84 (1%)

TABLE 6

Number of known-age White-faced Storm-Petrels recovered away from Mud Islands in each month. Excluded are 2 birds recovered as skeletons.

Months	Age					Totals
	1st year	2nd year	3rd year	4th year	5th year	
Jan.	1	1				2
Feb.	30					30
Mar.	4					4
Apr.	1					1
May						0
June	1					1
July			1			1
Aug.						0
Sept.				1		1
Oct.					1	1
Nov.		1				1
Dec.						0
Totals	37	2	1	1	1	42

examination of the banding schedules shows that this individual was probably banded as a nestling at Mud Islands on 29 January 1961.

Recoveries of Birds Banded as Adults

One hundred and three (60%) of the 172 recoveries of birds banded as adults were in the first three years after banding and the oldest bird was recovered 12 years after banding (Table 7). Only one of the 157 birds banded with aluminium bands prior to 1962 has been recovered whereas there have been recoveries of monel or stainless steel bands for each year that such bands were used.

One hundred and sixty-five recoveries (96%) were of birds recaptured in subsequent breeding seasons at Mud Islands. Dessicated remains of four birds were found on South Channel Island and therefore the elapsed time between banding and death could not be determined. Three others were found dead within a 15 km radius of Mud Islands between October and January in the first

TABLE 7

Recoveries in years after banding of White-faced Storm-Petrels banded as adults at Mud Islands.

Year	No. banded	%Al. bands	Recoveries in years after banding												Total recovered	
			0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12		12-13
1955	1	100														0
1957	3	100														0
1958	70	100														0
1959	51	100														0
1960	13	100														0
1961	19	100		1												1
1962	31	0														0
1963	450	0	2	5	4			6	2					1		20
1964	247	0		9			4					2		1		16
1965	1 012	0	4	1	22		7			6	9	1	1	3	1	55
1968	367	69	2	2				1								5
1970	441	63	2		1	1	2		1	1		1				9
1972	38	0				1				1						2
1973	103	0	9		1		4		1	1						16
1974	618	66	2	11	3	5		1	1							23
1976	115	0	2	12		2	1									17
1977	590	16	4	2	1											7
1978	7	0		1												1
1979	89	0														0
1980	155	0														0
Totals	4 420		27	44	32	9	18	8	5	9	9	4	1	5	1	172 (4%)

and ninth year after banding. There have been no long distance recoveries of birds banded as adults.

Discussion

The band recovery rate achieved in this study (2%) and the few long-distance recoveries are similar to the results of previous banding studies of other hydrobatids. For example, over 70 000 British Storm-Petrels *Hydrobates pelagicus* have been banded in Great Britain and about 1 000 (1.4%) have been recovered, six of which were from the extremity of their wintering range (Lockley 1983).

Both our long distance recoveries, which were of one or two-year-old birds, were well to the west of Mud Islands. Additionally, a bird banded at Mud Islands in late January, 1919, was found dead near Port Fairy, 440 km to the west, 6 weeks after banding (Chandler 1959). These recoveries support the assumption, based on specimen material, that part of the Australian race *P. marina dulciae* winters in the northern Indian Ocean and Arabian Sea (Voous 1965, Bailey 1966). Imber (1984) presents evidence that some *P. m. dulciae* winter near the southern tropical convergence in the south-west Pacific. He also suggests that pre-breeders may form a large proportion of such birds. However, our few band returns suggest that birds hatched at Mud Islands move west into the Indian Ocean. The White-faced Storm-Petrel is largely absent from southern Australian waters between March and September, the period when it occurs in the northern Indian Ocean, although small numbers have been seen along the continental shelf off southern Australia in all months (D. Eades unpublished data). Clearly, further long-distance recoveries are necessary before the movements of birds from Mud Islands become clear.

As the sex and breeding condition of birds was not assessed at the time of banding, only limited breeding information can be derived. However, the results presented suggest that White-faced Storm-Petrels follow the usual hydrobatid pattern in the major aspects of their social and breeding biology (cf. Lockley 1983). It appears that pre-breeders first return to Mud Islands in their third year, although, due to the low recovery rate, it is possible that younger birds visited the colony and eluded capture. In

other species of storm-petrels which have been studied (e.g. British Storm-Petrel and Leach's Storm-Petrel *Oceanodroma leucorhoa*, Lockley (1983)) the age of first return to breeding colonies is also two to three years. These pre-breeders may visit several different colonies without landing before first breeding when four or five years old (Cramp and Simmons 1977, Lockley 1983). Thus, it seems likely that the three year old White-faced Storm-Petrels captured at Mud Islands were pre-breeders. It is also likely that a large proportion of the birds captured in mist nets were pre-breeders as Richdale (1965) found that only about one third of birds captured at Whero Island, New Zealand were breeding. Therefore, the problem of handled birds deserting their eggs or young may not have been as real as was thought since probably only small numbers of breeders were being handled. The few multiple recaptures and even spread of recaptures across the years after banding (Tables 5 and 7) suggest that most adults return annually to their natal colony. However, that some birds visit other colonies is clear from the recovery of seven birds from South Channel Island, 5 km to the east, where some 6 000-7 000 White-faced Storm-Petrels breed (Harris et al. 1980).

The apparent high mortality in the first few weeks after fledging is expected as the nestlings must fend for themselves immediately they have fledged. However, the comparative magnitude of this mortality is biased by the much greater probability of bands being returned from birds which die in Port Phillip Bay where beaches are crowded with people in late summer. Thus, the significance of this mortality is difficult to assess but the 0.4% band return in the first year of life does not seem to be excessive. Once the birds leave Port Phillip Bay, their pelagic life-style, small size and dispersal into small flocks (Voous 1965) would ensure that few birds are beachwashed and the chances of band recovery are minimal. Of nearly 6 000 beachwashed seabirds examined by D. Eades along ocean beaches 9-36 km west of Mud Islands between 1975 and 1978, only 36 (0.6%) were White-faced Storm-Petrels (D. Eades unpublished data).

The oldest known White-faced Storm-Petrel was in its seventeenth year when last recaptured (Table 5). This is well within the longevity records for other hydrobatids such as the British Storm-Petrel (20 years) and Leach's Storm-Petrel (24 years) (Lockley 1983).

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