

FINDING THE BURROWS OF CHATHAM ISLAND TAIKO *Pterodroma magentae* BY RADIO TELEMETRY

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ABSTRACT

The Chatham Island Taiko (Magenta Petrel) *Pterodroma magentae* is endangered, with a population of about 50 birds. Conventional searches from 1970 to 1986 failed to find its breeding sites. Trials of radio transmitter packages attached to Grey-faced Petrels *P. macroptera gouldi* and to six Taiko in 1982-1986 were satisfactory. In a major effort to find burrows, Taiko were caught and radio-tracked over three months in late 1987. Twelve Taiko were caught at night with the aid of lights. Ten birds were each fitted with a transmitter; all flew out to sea after release. Birds were tracked on 16 later occasions. Two tracked birds landed 4-6 km inland in dense bush. On subsequent searches at the bearings at which the signals became stationary, five burrows were found, in two areas, 4 km apart. During a similar operation in 1988 no Taiko were caught. Despite extensive searches, these were still the only breeding areas known in late 1993.

INTRODUCTION

The Magenta Petrel *Pterodroma magentae* was originally described from a specimen taken at sea in the winter of 1867 near 40°S, mid-way between the Chatham Islands and South America (Giglioli & Salvadori 1869). Bourne (1964) suggested that the species was the Chatham Island Taiko, known only from recent fossil bones and local lore (Fleming 1939). Birds were sighted several times at lights in Tuku-a-tamatea (Tuku) Valley, south-west Chatham Island (Figure 1) from early 1973; eventually, two Taiko were captured there (in 1978, Crockett 1979), and found to be indeed the Magenta Petrel (Crockett 1994).

The first Chatham Island Taiko Expedition, led by D.E. Crockett (DEC) began searching for Taiko breeding burrows in January 1970, in the south-west of Chatham Island. New Zealand Wildlife Service parties led by M.J. Imber (MJI) searched elsewhere in the archipelago, on lesser islands, islets, and coastal cliffs, from 1975. These searches used conventional methods: looking for burrows of suitable size (similar to, or slightly less in cross-section than, those of the widespread Sooty Shearwater *Puffinus griseus*) and identifying the burrows' occupants; listening at night for petrel calls; probing

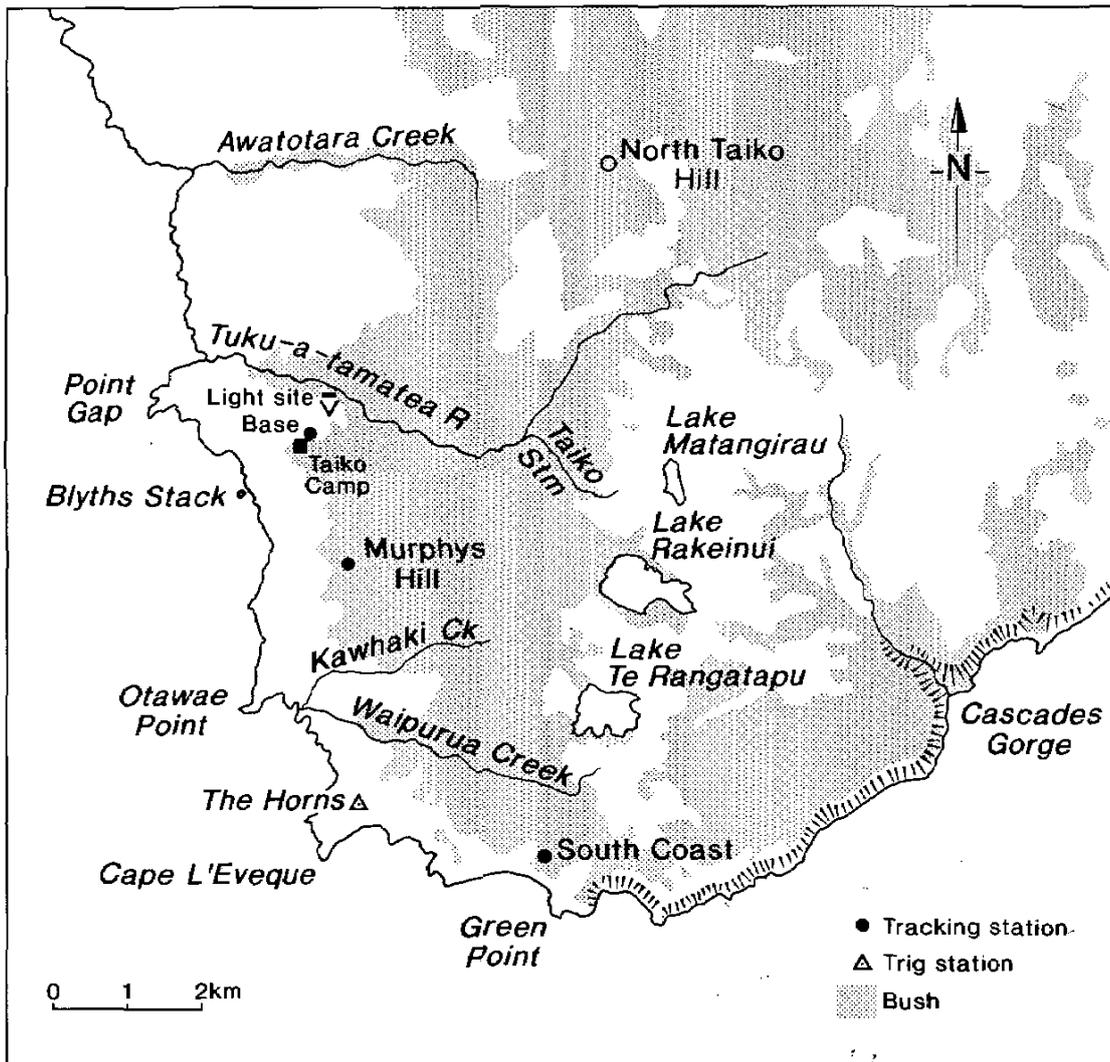


FIGURE 1 – Map of south-west Chatham Island showing features mentioned in the text

the night sky with spotlights and floodlights; picking through Brown Skua *Catharacta skua lomnbergi* middens; and collecting information from Chatham Islanders, particularly muttonbirders (an illicit practice, but still common). All searches up to 1982 failed. Taiko were still seen and caught at lights in the Tuku Valley but no recent burrows had been found, either there or elsewhere.

As a result of the continued lack of success of conventional techniques, it was decided to experiment with radio transmitters in an attempt to locate burrows. In 1982, H.A. Best and other Wildlife Service staff were tracking Kakapo *Strigops habroptilus* (a nocturnal flightless parrot) by radio telemetry. The techniques used in that study were modified for use on petrels. We knew then of no other radio telemetry studies on seabirds.

Taiko were known to be very rare and endangered, so most early trials were done on Grey-faced Petrels *Pterodroma macroptera gouldi*. This abundant species is slightly larger than Taiko (c.540 g cf. c.470 g), and the Whale Island (Bay of Plenty) population was being studied by MJI.

Preliminary radio telemetry trials

The trials covered methods of attachment, the effect on breeding performance and body weight over time, and optimising construction and coating for compactness, lightness, and resistance to sea-water. Most important, to ensure the safety of the birds, the transmitter package for use on Taiko had to meet two stringent criteria. The device had to fall off the bird as soon as possible after the battery expired (it was unlikely that a Taiko fitted with a transmitter would be recaptured); and it had to weigh less than 5% (c.23 g) of the weight of a Taiko – preferably less than 3% (c.14 g).

To ensure that the device would fall off, it was mounted on the tail feathers so that it would be shed at the annual moult. The weight limit was more intransigent. The battery contributed about 70% of the weight of a transmitter package; battery life (hence transmitter life) was directly proportional to its weight, so the weight limitation restricted transmitter life. Battery and transmitter technology improved greatly between 1982 and 1987 – and continue to do so. Batteries available within the weight restriction in 1982 allowed a transmitter life of just a few weeks; in 1987, they could power a transmitter for 4 months.

On 7 to 9 May 1982, dummy transmitters (c. 15 g) were attached to six male Grey-faced Petrels occupying burrows. The devices consisted of a small block of wood about the size of a battery plus transmitter, on an aluminium base plate. Each was clipped around the base of three tail feathers, including the central two (Figure 2), and tied at its outer end to the two central tail feathers by reef-knotted multifilament nylon fishing line, without adhesive.

Four birds were recovered, between 12 and 21 July. Three had removed the device, but one retained it and was incubating. Its weight of 625 g was within the range of initial weights for petrels that successfully complete their incubation spell (590-760 g, Imber 1976). Two birds were not recaptured; they were probably either non-breeders, or their nest visits did not coincide with ours. We concluded that a stronger attachment, with glued ties, was needed.

In July 1982, a functioning transmitter was attached by glued ties to a Grey-faced Petrel caught at night on the ground and so presumably a non-breeder. No signals were received during the succeeding seven nights. This supported the impression, gathered from earlier studies of the Procellariidae, and confirmed in this study, that non-breeding individuals visit colonies infrequently.

Transmitters were attached to three Taiko in November 1982. To keep the weight of the devices down to 14-15 g (c.3% of body weight), batteries giving a calculated life of only three weeks were used. As Taiko caught at Tuku light station were considered to be non-breeders, and non-breeding petrels were suspected to visit colonies infrequently, we did not prepare for a full tracking operation with these transmitters. The main objective was to gain experience in attaching the devices, and to observe and track Taiko with a hand-held aerial after release. All three Taiko were tracked flying southwest to south, out to sea, after release. Two released in daylight were seen to fly normally. No signals were received during intermittent

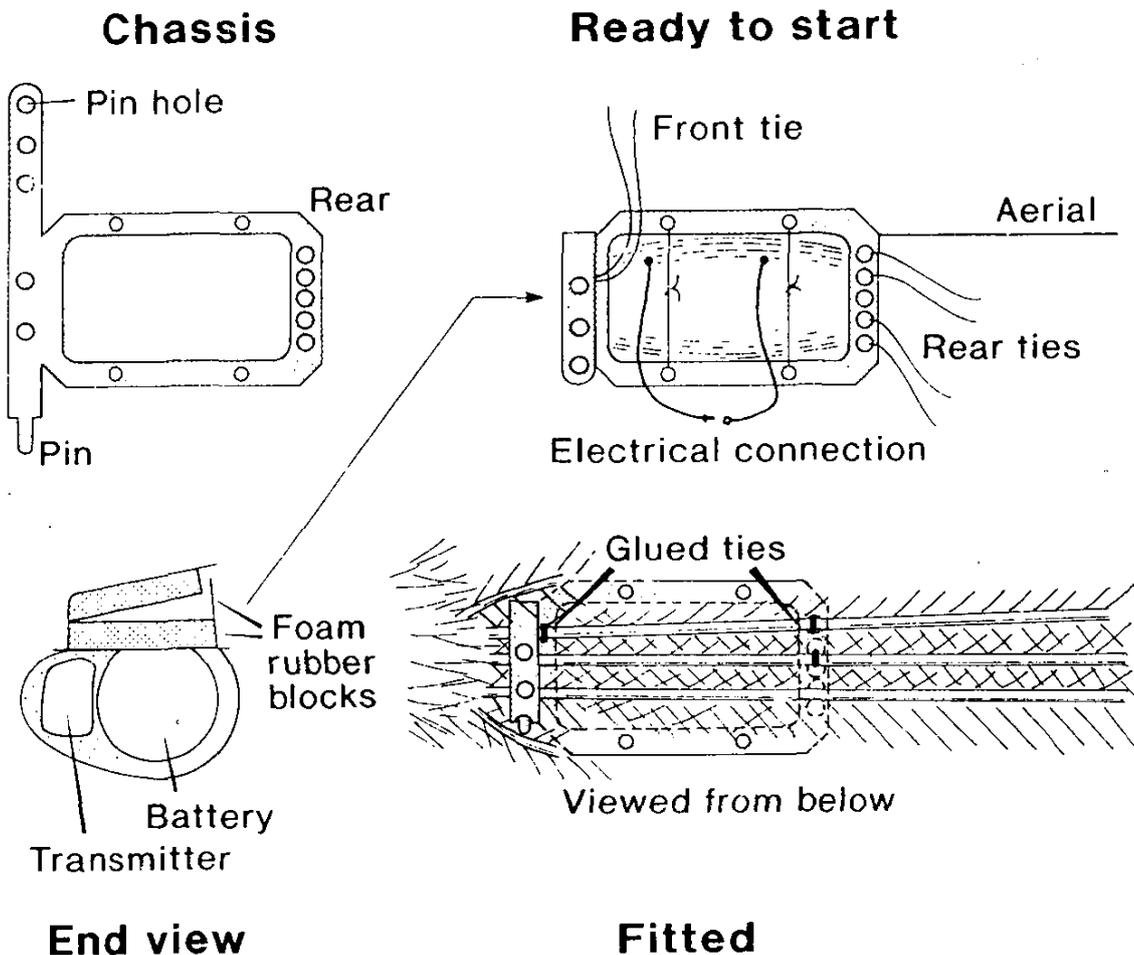


FIGURE 2 – Method of construction and attachment of the transmitter package used on Chatham Island Taiko in 1987

surveillance over 10 nights after release, using an omnidirectional and hand-held antennae.

When one of the three Taiko was recaptured in November 1983, its tail was in good order. Because this Taiko had been consistently the lightest adult caught – 412 g when first caught in October 1982, 414 g when the transmitter was attached, 418 g in November 1983 – it appeared that the transmitter could safely exceed 15 g.

Further trials with dummy transmitters were carried out on Grey-faced Petrels in 1985, to test security of attachment (including the aerial), and any effect on the petrels' weight. The devices were attached to 10 petrels and included a dummy aerial which was also tied to one of the central tail feathers. They weighed 10-12 g (2% of body weight). Three of the four birds recaptured while incubating 11 to 12 weeks later still had their transmitters. Their body weights were within the range for successful breeders during incubation. The petrel without the device had bitten off its tail feathers at the point of tying and gluing. The other three had separated the aerial from the feather it was tied to, so from then on the aerial was left free. Although only 40% of the birds in the trial were recaptured, it was felt that, given

more time, probably all of the 10 petrels in this trial could have been recaptured.

Three functioning transmitters were put on non-breeding Grey-faced Petrels in July 1985. Receivers were monitored intermittently over the following 9-10 nights but no signals were heard. Three Taiko were fitted with transmitters in October 1985. At 18.5-18.8 g (c. 3.8% of body weight) these transmitters were at the upper limit, but contained lithium batteries that could supply power for over two months' operation. No useful signals were, however, recorded during about two months of monitoring at four stations, albeit by inexperienced observers.

In the final trial on Grey-faced Petrels, in 1986, two functioning transmitters (as used on Taiko in 1985) were put on birds taken from burrows on the night of 26-27 April. After 76 days, one of the transmitters was recovered in good working order. As it approached Whale Island at dusk on 11 July, the petrel was tracked with a hand-held aerial and caught a few hours later in a burrow 8 m from where it was taken in April. The other bird was not found between 8 and 15 July 1986, but was incubating in its burrow, without the transmitter, in 1987. By 1987, techniques and equipment had been developed to where it was thought possible to attach to Taiko transmitters that would not adversely affect the birds, would stay on at least 75% of them, and would function for over two months.

METHODS

Catching Taiko

Until 1987, all live Taiko seen at the Chatham Islands were found by attracting them to lights at night, over a ridge above the south bank of Tuku River (Figure 1). The lower 4 km of the river run northwest and the valley was long thought to be a fly-way for Taiko. The results reported here do not support this view. The light system, its position, orientation, operation, and best weather conditions for success are described in Crockett (1994).

The behaviour of Taiko at the catching site suggested that the light attracted them, rather than intercepted them in passing. No Taiko was seen to land when only the floodlight was on, and Taiko often flew back into its beam after escaping from the spotlights. The spotlights seemed to confuse many Taiko. From first sighting of a Taiko to when it landed varied from c.15 s to nearly 30 min. Each bird was placed in a separate holding box; most were taken 1 km to base camp for processing (Crockett 1994).

Transmitters (1987-type)

The transmitter package was mounted on a chassis (Figure 2) made from 0.6 mm aluminium sheet. To the chassis were fixed the transmitter (2-stage, Titley Electronics Ltd), aerial and battery; the chassis was attached to the bird's tail. The battery was ½AA Lithium that allowed a life of 3-4 months. The transmitter was bound to the battery with thin insulation tape, and the combination was given several coats of an insulating compound. The end of the aerial was also dipped in this compound to seal it against absorbing sea-water by capillary action.

The transmitter package was tied to the chassis with multifilament nylon fly-fishing line backing (10 kg test). Then the dorsal surface was coated with dental acrylic, leaving only the front clip and the underside with an exposed gold connecting pin uncoated. The connecting pin, to complete the electrical circuit, was engaged and the underside sealed with dental acrylic, immediately before attaching the device to the bird.

Ten transmitters were prepared, all on similar frequencies (160.2600-160.2655 MHz), except one (160.2062 MHz, left over from 1985), because it was expected that each transmitter would not be tracked for long. The advantages of different frequencies, and hence identifiable individual Taiko, were outweighed by the necessity of being able to monitor all transmitters constantly. The mean weight of the 10 devices used in 1987 was 16.5 g (range 16.0-17.2 g) and they represented a mean of 3.53% (range 3.27-3.72%) of the weight of the Taiko to which they were attached.

Attaching the transmitter package

Confidence and care in handling were required to ensure that the Taiko did not become stressed. In 1986, a Grey-faced Petrel died while being fitted with a transmitter, from what was probably heat-shock caused by constant struggling. In 1985 a Taiko had to be cooled off in water after beginning to pant.

In early trials, transmitters were attached mainly under the tail, because the bulk of the first transmitters caused them to protrude excessively if placed dorsally. However, the more compact devices available in 1987 could be attached dorsally. This position had the advantage that the petrel was laid on its back during attachment, and it could be induced to sleep during the process. The Taiko was held as loosely as possible, with no pressure on the body, the head in darkness but not closely confined, and the feet were exposed for cooling. The best position, for all but the most difficult birds, was on a table between the operator's elbow and side, facing behind, with a dense cover from the operator's shoulders down over the bird's anterior. An assistant helped with parting the undertail coverts.

The bases of three central tail feathers were exposed and the basal clip of the device was worked around them, closed and secured with the bend-over pin (Figure 2). The device was positioned to give 10 mm clearance between it and the pygostyle. The two rear ties were then reef-knotted to each central quill, with a little of each vane at the tying point being cut off to facilitate subsequent gluing, and any excess tie removed. This process was repeated with the front tie, to one of the same quills. All three ties were then coated with fast-setting epoxy glue ("5-minute Araldite[®]"), the glue being also worked down onto the adjacent surface of the device. When the glue had set, the surrounding feathers were tidied and the bird was ready for release.

Radio telemetry stations

The receiver stations were developed from those used to track Kakapo on Stewart Island. A canvas shelter on an angle-iron frame housed the electronic equipment and operators at the foot of a 10-20 m mast. The directional aerial, a 12-element yagi, was at the masthead.

Several null-peak receiving stations were used in the 1985 telemetry work on Taiko. Two antennae on each mast were wired so that a minimal signal was heard when they were pointed directly at the signal source; the strongest signals were just each side of the aural null. The system had worked well with the flightless Kakapo, but we considered that the system would be difficult for inexperienced operators to use for tracking fast-moving Taiko. In 1987, therefore, a simple peak-gain system – strongest signal with antenna pointing at the source – was used. Signal strength varied little at up to about 5° either side of peak.

The mast-plus-aerial was trained by a 0.4 m pipe or wood tiller near its base. Over-rotation, which would have broken the aerial lead on the guy-wires, was prevented by a stake driven to stop the tiller where fewest transmissions were expected. Azimuth was read from a compass rose attached below the tiller. The rose rotated with the mast against a lubber line on the stationary base, set to give 0° at Magnetic North. The tracking compass was calibrated against either the maximum signal from a transmitter at a distant point of known bearing (from a map), or simply by aligning the aerial on a distant feature of known bearing. A field compass was used to check the alignment. The Magnetic bearings were adjusted later to True, assuming Variation to be 24°E.

A shorter, omni-directional, aerial also erected beside the shelter as a continuous monitor was rarely used because the main aerial had a long range and located incoming transmissions first, even with intermittent (10-15 min spaced) sweeps.

Siting tracking stations (Figure 1)

As burrow locations were unknown in 1987, receiving stations were placed to cover as much of the southern part of the archipelago as possible. Stations were planned at the summits of South East Island and Mangere Island (MI) to cover all the islands around Pitt Island, at two points along the south coast of Chatham Island, and at Base Camp (B) and at Murphy's Hill (MH) (to cover the interior and west coast of the southwestern section of Chatham Island). Of the two southernmost stations, only that on MI – near the highest point of the Chatham Islands - was established, because of shortage of personnel. Problems of access meant that only an intermediate site above Green Point (South Coast, SC), rather than sites near The Horns and Cascades Gorge, was set up on the southern coastline. With the assistance of the yacht *Totorore* (G. Clark) a low level station was set up later on Houruakopara Island (HI), off Cascades Gorge. Stations varied in their ease of establishment. B and MH were accessible, or nearly so, by off-road vehicles, but the very successful SC was carried on foot for 7 km along a coastline intersected by deep valleys. MI (where a hut simplified operations) and HI were set up by sea.

At peak effort, during November 1987, five land-based stations were operational. Another receiver was aboard *Totorore*, which frequently anchored overnight about 2 km southwest of Cape L'Eveque, but it was very difficult to radio-track Taiko from such a low and unstable platform.

Communications

Good radio contact between stations was essential. The Base station radio was the most powerful. Portable sets were used at other stations – the smallest at MH and for field exploration parties. Radio schedules were set daily, but were never less than hourly during the evening. Stations actually tracking Taiko usually remained on air. Although there was some conflict with other stations on the same frequency, it was not sufficient to warrant using a separate frequency.

Radio-tracking Taiko

Operations began each day at about 1800 h local time, with a system check using a test transmitter. Thereafter, the directional antenna was swept through 360° at least every 15 min. Time, bearing, relative strength, changes in strength, and behaviour of any signal were logged.

SC, at 270 m above Pitt Strait, commanded the southern approaches to Chatham Island. It was the third operational station, and was immediately successful as an early warning station. The procedure developed was: SC began sweeps every 10-15 min from c.1800 h until a contact was made; from c.1900 h, at least hourly radio schedules were maintained to B, and to any other occupied tracking stations; if contact was made with a Taiko transmitter, B and HI were alerted and began sweeping if they were not already operating; MH was manned from Base, and sometimes MI had to be manned from its base hut if it was not already operating; *Totorore* was alerted, if on station. The urgency depended on time to full darkness, as Taiko remained offshore till then. With an incoming Taiko after dusk, all stations had to be on full alert.

Tracking usually continued throughout the hours of darkness and until contact was lost, when a Taiko came in, or was believed to have been in a burrow during the previous day. If no signals were received or anticipated, stations sometimes closed down soon after midnight, or did not operate, but SC was always active until at least 0200 h, and usually until dawn.

Searching for burrows

It was planned to find burrows by locating a stationary signal on land using portable receivers. Where that was impracticable, because of time limitations, remoteness, or density of vegetation, we plotted the bearings of the landing area, using aerial photographs and a map to familiarise ourselves with the terrain, and sent two or three experienced bushmen to search the areas from fly-camps.

RESULTS

Capture of Taiko

Tuku light station began operating on 9 October 1987 after the full moon. Transmitters were fitted to the first 10 Taiko caught. The first Taiko was seen, caught, and fitted with a transmitter on the night of 10/11 October. Further Taiko were caught for fitting with transmitters on 15, 16, 17 (2) and 25 October, and on 2, 10 (2) and 16 November. We caught more Taiko

TABLE 1 – Taiko at the Tuku light station in 1987, in 12-day periods. FM, full moon, light not operated, duration of period depended on weather conditions and priorities of personnel.

Dates	Number of Taiko	
	Seen	Caught
9 Oct - 20 Oct	8	5
21 Oct - 1 Nov	6	2
FM		
9 Nov - 20 Nov	7	4
21 Nov - 2 Dec	1	0
FM		
6 Dec - 17 Dec	3	1
TOTAL	25	12

TABLE 2 – Numbers of Taiko seen and caught per hour (local time) from dusk to dawn at Tuku light station in 1982, 1983, 1985 and 1987 (combined data).

Number	Local time (hours)								
	20-21	21-22	22-23	23-24	24-01	01-02	02-03	03-04	04-05
Hours of observation	17	30	73	80	65	58	49	39	10
Taiko seen	0	7	9	6	4	9	7	6	1
Taiko caught	0	4	3	5	2	4	2	3	1
Hours/sighting	∞	4.3	8.1	13.3	16.3	6.4	7.0	6.5	10.0
Hours/capture	∞	7.5	24.3	16.0	32.5	14.5	24.5	13.0	10.0
Mean hours/capture		15.3			15.6				

TABLE 3 – Rates of sighting of Taiko (hours/Taiko sighting) and catch rates of Taiko in 1982, 1983, 1985, 1987 and 1988, at Tuku light on Chatham Island. (For 1982-1985, data only from MJI; 1988 data include 14 hours observations at a second light at the southwest end of Murphy's Hill - 1 Taiko seen).

	Year			
	1982 + 1983	1985	1987	1988
Observation time (h)	124	82	264	308
Taiko seen	17	10	25	14
Hours/sighting	7.3	8.2	10.6	22.9
Taiko caught	9	3	12	0
% caught	53	30	48	0

than expected (Table 1), but this can be attributed to the continuous effort put in at the light. Most Taiko were seen at the light early and late in the night (Table 2).

Although the light station operated throughout October to mid-December 1988, no further Taiko were captured for radio telemetry. Only two were seen at the Tuku light before 0045 h; the rate of sighting was a third of that in 1982 and 1983 (Table 3). Whereas most Taiko had reacted to the spotlights (a prerequisite for capture) in previous years, of 14 seen in 1988 only three did so; the other 11 flew unhesitatingly onwards.

Tracking results

Signal characteristics Two particular traits of signals noted were shearwatering (a regularly oscillating signal in rhythm with the bird's shearwatering flight, indicating that it would be out at sea), and a steady signal (associated with birds over land or near the coast). The signal from a bird on the sea resembled shearwatering but tended to oscillate more severely, and would be stationary.

Observations

The times and directions taken by selected tracked Taiko are shown in Figures 3-11. Text descriptions of these tracks are abbreviated. No signals were received on the missing intermediate dates.

10/11 Oct: First Taiko, released 0315 h, bright moonlight; tracked at 220° to 200° from B for 1.5 h.

15 Oct: Second Taiko, released 1250 h; gained height (200 m), tracked at 240° veering to 210° from B, until 1440 h.

17 Oct: Third Taiko, released 1118 h; tracked at 175° from B for 7 min until out of line-of-sight of B (only station operating), presumed to have descended beyond southern coast.

18/19 Oct: Two of the three Taiko previously fitted with transmitters were tracked. At 2001 h, on 112° (SC), apparently approaching through Pitt Strait; by 2040 h (after full darkness) very close at 94° (SC), moving north towards

coast near Cascades (where 200 m cliffs created a radio-shadow for SC); at 2047 h 200° (SC) passing westwards quickly along coast towards Cape L'Eveque, SC lost signal at 2050 h. Signal regained by SC at c.200° at 2102 h, then over coast and passed very close north of SC at 2105 h to 2111 h. Reception lost intermittently, apparently as bird flew down into Waipurua or Kawhaki Valleys, before turning east to the cliffs east of Green Point at 2120 h, again very close south of SC at 2129 h, then stationary on Green Point soon after 2138 h. Stationary until 2258 h, when all three personnel at SC left with hand-held receiver to try to find it (in hindsight, one should have continued tracking). The unfamiliar terrain was more difficult than expected and the search was aborted at 2355 h when only a faint signal was detectable in the original direction. After tracking resumed at SC at 0030 h, no signals were heard until 0230 h, when the signal from the fifth Taiko was first received.

In late October 1987, there were three or four "active" burrows (apparently occupied by Sooty Shearwaters) on Green Point. The Taiko may have landed to prospect at the burrows whose bearing from SC matched that at which the signal was stationary for >1 h. It may have flown back to sea sometime between 2300 h and 0030 h when no regular tracking was done, as no subsequent signal could be ascribed to this bird. The Green Point burrows have disappeared (MJI, pers. obs. 1 Feb 1992) through the combined effects of predation of the shearwaters, pig-rooting, and erosion and trampling by grazing stock, as is happening to all remnant Sooty Shearwater colonies on the coast of Chatham Island.

B began monitoring at 0155 h: from 0209 to 0218 h an intermittent signal was received at 90°-95° from B but not SC. Signals from this transmitter were not received again until 0304 h when it was tracked down the Tuku Valley (not seen at the light), then out to sea west and southwest of B; signal received by SC and tracked at 0340 h (265°), veering to 235° (SC) at 0530 h when last heard. This may have been the bird later tracked three times to a burrow in Taiko Valley; it may have come in undetected the previous night, when only B was listening, and that infrequently.

Fourth Taiko, released 1320 h; tracked at 234° veered to 214° from B at 1523 h when signal lost; 230° from SC, veering to 217° between 1431 h and 1532 h. Triangulation on last signal received at both stations gave range of c.55 km. Fifth Taiko, released 0155 h, tracked on 240°(B); stationary for 35 min just offshore (probably washing); veered to 200° from B when tracking stopped at 0350 h; further veered to 160° (SC) at signal end at 0420 h.

20/21 Oct: (Figure 3): A Taiko approached from SSW, flew inland 20 min after dark, and landed, presumably at a burrow, in the catchment of an unnamed tributary of Tuku River (now called Taiko Stream), west of Lake Matangirau. The stationary signal was intermittent for the next 2.5 h. Further tracking on 21/22 Oct allowed a more accurate plot of the transmitter position (see below).

21/22 Oct: (Figure 3) Signal received by B from an easterly bearing 1 h before other stations; signal was intermittent until about 2328 h after which it was tracked out over the coast, and continuing south, to the west of Pitt Island.

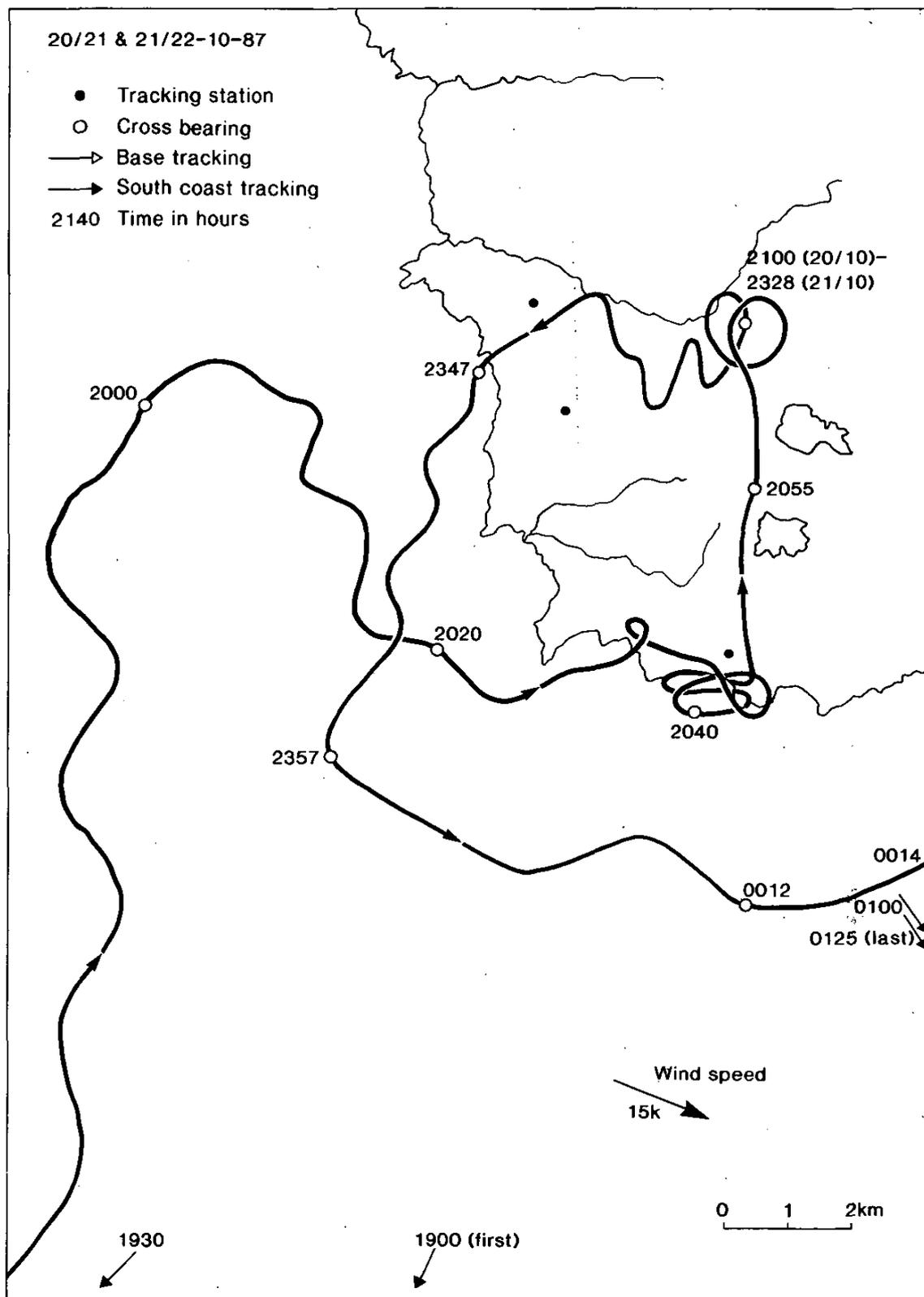


FIGURE 3 – Path of Taiko tracked on 20 October and on 21/22 October 1987. Full darkness at 2030 h (NZ Standard time).

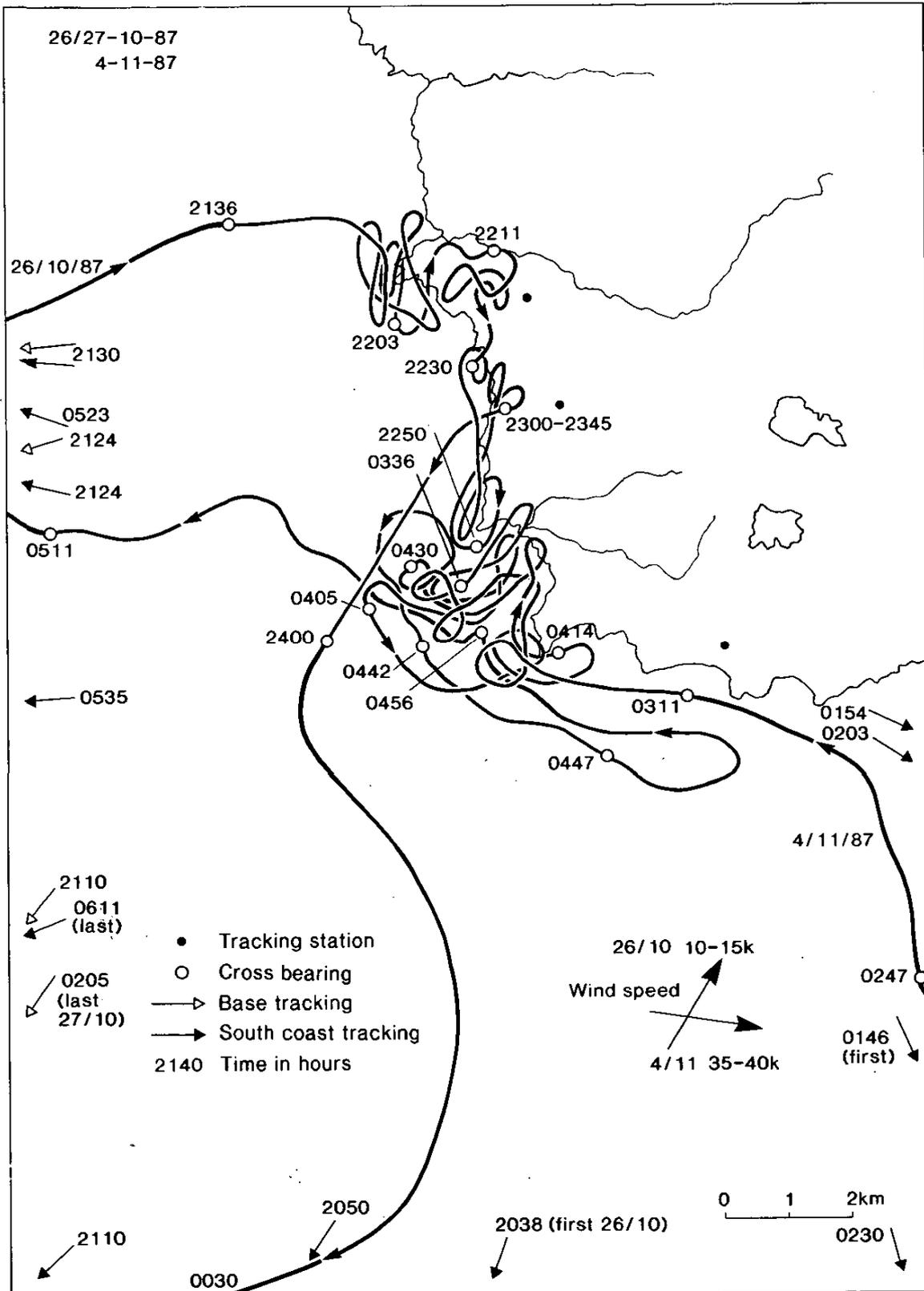


FIGURE 4 – Path of Taiko tracked on 26/27 October and 4 November 1987. Full darkness at 2138 h and 2150 h (NZ Summer Time) respectively.

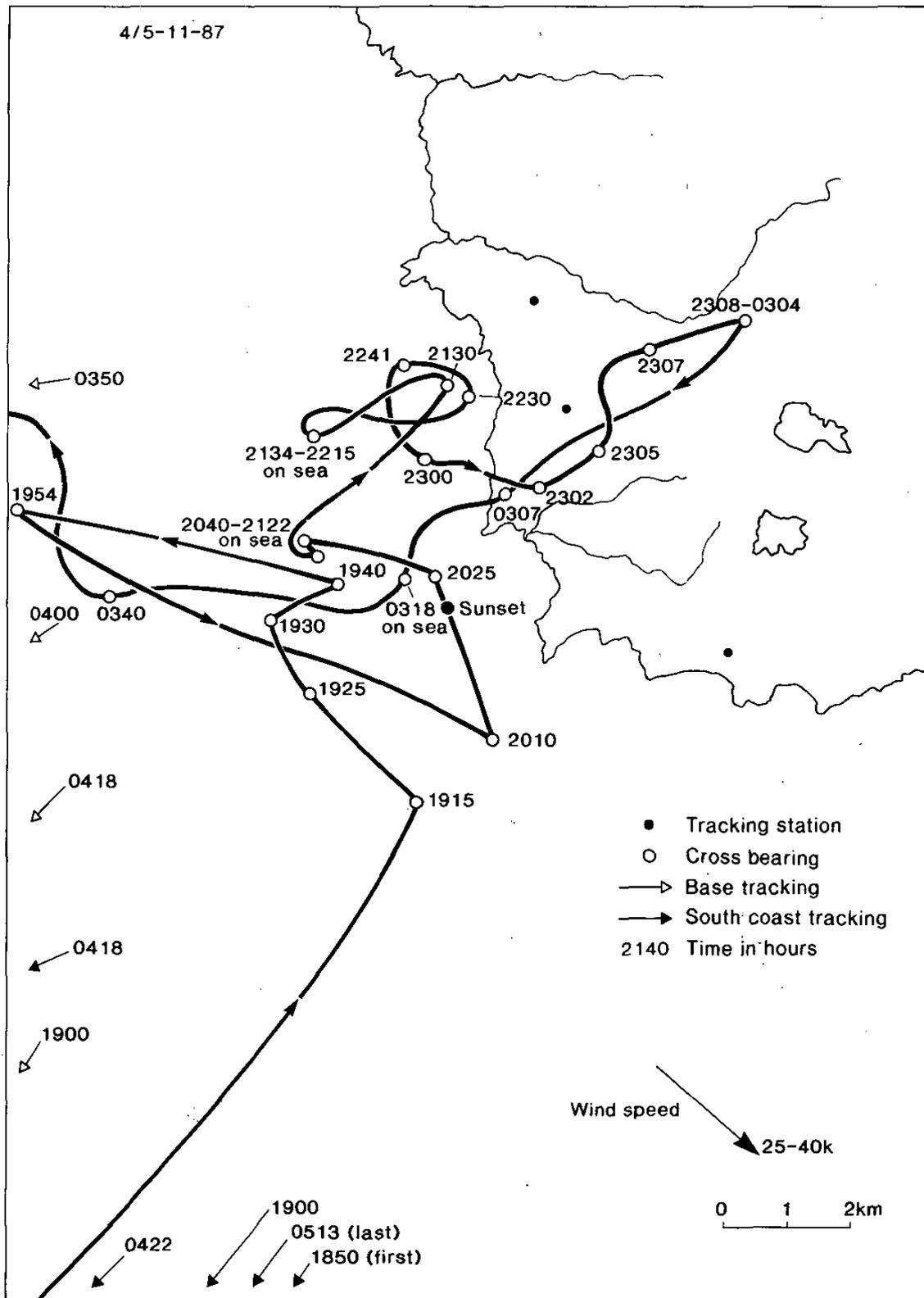


FIGURE 5 - Plots for Taiko that landed by Taiko Stream Valley on 4/5 November 1987. Full darkness at 2151 h.

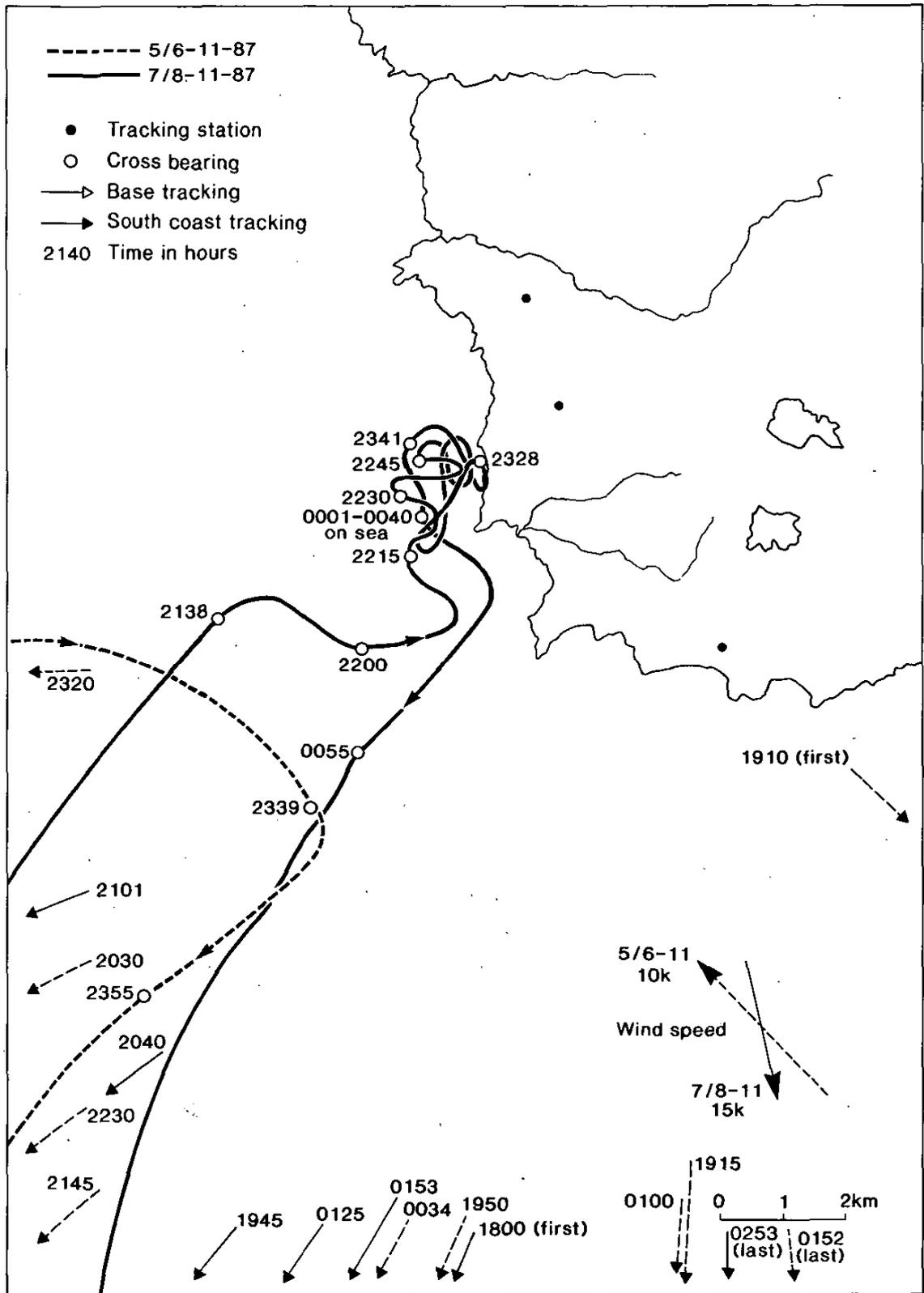


FIGURE 6 - Plots for Taiko tracked on 5/6 and 7/8 November 1987. Full darkness at 2152 h and 2155 h respectively.

Signals received at B, MH, and SC at 2324 h fixed the origin of the stationary signal near the middle section of Taiko Valley. The precision of the fix was further improved when what was probably the same bird landed there on 4/5 and 10/11 Nov.

26/27 Oct: Sixth Taiko released, 1745 h, tracked SW then SE. Signals ceased at B at 1822 h. SC received first strong signals at 1753 h 280° , veering gradually to 115° (SC) at 2035 h when last heard (judged by signal strength and bearing to be south of Pitt Island). Another incoming Taiko (Figure 4) was then tracked. Its signal was stationary between 2300 and 2345 h near the clifftop, directly below MH. The last signals received at SC were unusually weak. At 2400 h a hand-held receiver was taken to the clifftop, near where the Taiko was thought to be on the ground; from 0015 h to 0100 h, it monitored a good signal, apparently only on the bearing of the main stack off Blyth's (Figure 1). However, the signal was vertically polarised (strongest signal with antenna vertical, normal = horizontal antenna) which may be a feature of reflected signals. Although the Taiko appeared to have landed on that stack and entered one of the many prion burrows there, the phenomenon was repeated on 12 Nov when we clearly showed that the stack reflected radio signals. A Taiko southwest of Cape L'Eveque, whose transmissions could not be received directly by a portable receiver at Blyth's clifftop, could appear to be stationary on the stack. We monitored Blyth's Stack for signals for the next three nights, but heard nothing.

2/3 Nov: Full moon. Seventh Taiko, released 0000 h; tracked westwards, 275° from B at 0030 h, then 304° from 0055 h until contact lost at 0122 h. Wind strong, SW.

3/4 Nov: (Figure 4) Tracked by SC alone, Taiko flew about in bright moonlight; wind W, gale. Signal did not become stationary; last heard at sunrise.

4/5 Nov: (Figure 5) Bird tracked inland to Taiko Valley; good fix from B (95°) and MH (64°) over next 4 h; during which stationary but signal lost 17 times (for 1-22 min, mode 3-5). The bird may have been entering and leaving a burrow. After departure, the bird was stationary for some time on the sea, probably washing.

5/6 Nov: (Figure 6) Tracked by SC, signals almost constant; bird probably stayed far out at sea.

7/8 Nov: (Figure 6) Close to cliffs at 2328 h; possibly landed; signals lost at B and MH for 1-3 min.

10/11 Nov: (Figure 7) Presumably same bird visited Taiko Valley again, and behaved as previously: signal intermittent as if bird entering and leaving burrow throughout time plot was stationary. Bird approached Tuku light three times, but did not fly into the beam.

11/12 Nov: Eighth Taiko, released 1504 h; tracked southwards, close around Cape L'Eveque; last signal at B at 1523 h; SC tracked until 1650 h on 174° .

Ninth Taiko (named "Lone Ranger", LR; only bird on 160.206 MHz), released 1958 h. Tracked WNW; last heard from B at 2135 h, on 285° . Another Taiko approached from S, wind light (Figure 8); for $\gt 10$ h. Tracked as flying over Taiko Valley five times but signal did not become stationary;

also tracked SE to Cascades Gorge area (2355-0017 h); only MI (at 27 km) received signals (strong), then MI lost contact for 7 min when the Taiko probably flew deep within the winding gorge. At 0130 h, the signal appeared to remain stationary for about 20 min on Blyth's Stack; hand-held receiver taken to adjacent clifftop by 0200 h received diminishing vertically-polarised reflected signals.

15/16 Nov: Tenth (last) Taiko, released 1950 h. Tracked SW by B; signal received by SC at 2000 h when fixed just off Cape L'Eveque; last heard on 212° from SC at 2144 h.

17/18 Nov: (Figure 9) Two Taiko tracked; neither signal became stationary. Tracking facilitated by difference in precise transmitter frequency, well separated (260/1 v. 260/4) on receivers. No evidence of interaction between the two birds.

5/6 Dec: (Figure 10) SC picked up weak signal from LR from 2351 h to 0011 h, and briefly 40 min later, to SE. The bearings suggested that this Taiko was tracked when flying beyond the far side of Pitt Island, probably 60 km away.

6/7 Dec: (Figure 10) LR tracked inland, well to N, but a good fix was not obtained on its last position because it was too far from tracking stations. It appears to have landed, as no further signals were heard until 0324 h when it was stationary on the sea near Waitangi Harbour, probably washing after working in a burrow.

11 Dec: (Figure 11) LR tracked again, on different course to 6/7 Dec, but signal again became stationary at fix of that date. No further signals received from it, or any other transmitter, although the general bearings where it disappeared were closely monitored over the next few nights. A search in the area with a portable receiver on 12/13 Dec was unsuccessful. LR probably departed on 11/12 Dec and may have flown E over the island (where it would have been difficult to detect) because of an increasing SW wind.

12 Dec 1987 – 4 Jan 1988: No signals received. MH closed on night of 11 Dec; MI at 0230 h on 13 Dec; SC at 0200 h on 15 Dec; B continued nightly until 0300 h on 4 Jan.

Searching for Taiko burrows

Oct-Dec 1987

On 22 October, the South Coast team visited Lake Rakeinui, on the fringe of the area where the Taiko tracked on 20/21 October may have landed. I. McFadden and G. Taylor swam to an islet but found no petrel burrows; none had been found by S. Wood on 26 November 1982. The South Coast party made the first survey of the valley of Taiko Stream on 24 October but had limited time and found no burrows.

From 4 November, A. Plant, G. Murman, and MJI camped on the edge of the "clears" west of Lake Matangirau, and explored Taiko Stream catchment. It comprises the main stream and two tributaries joining it from the northeast. GM found the first burrow ("Tuku 1") on 5 November on the southwest flank of the main valley, 0.5 km from the "clears". The burrow looked well-used and there was a freshly-cast white ventral feather at its

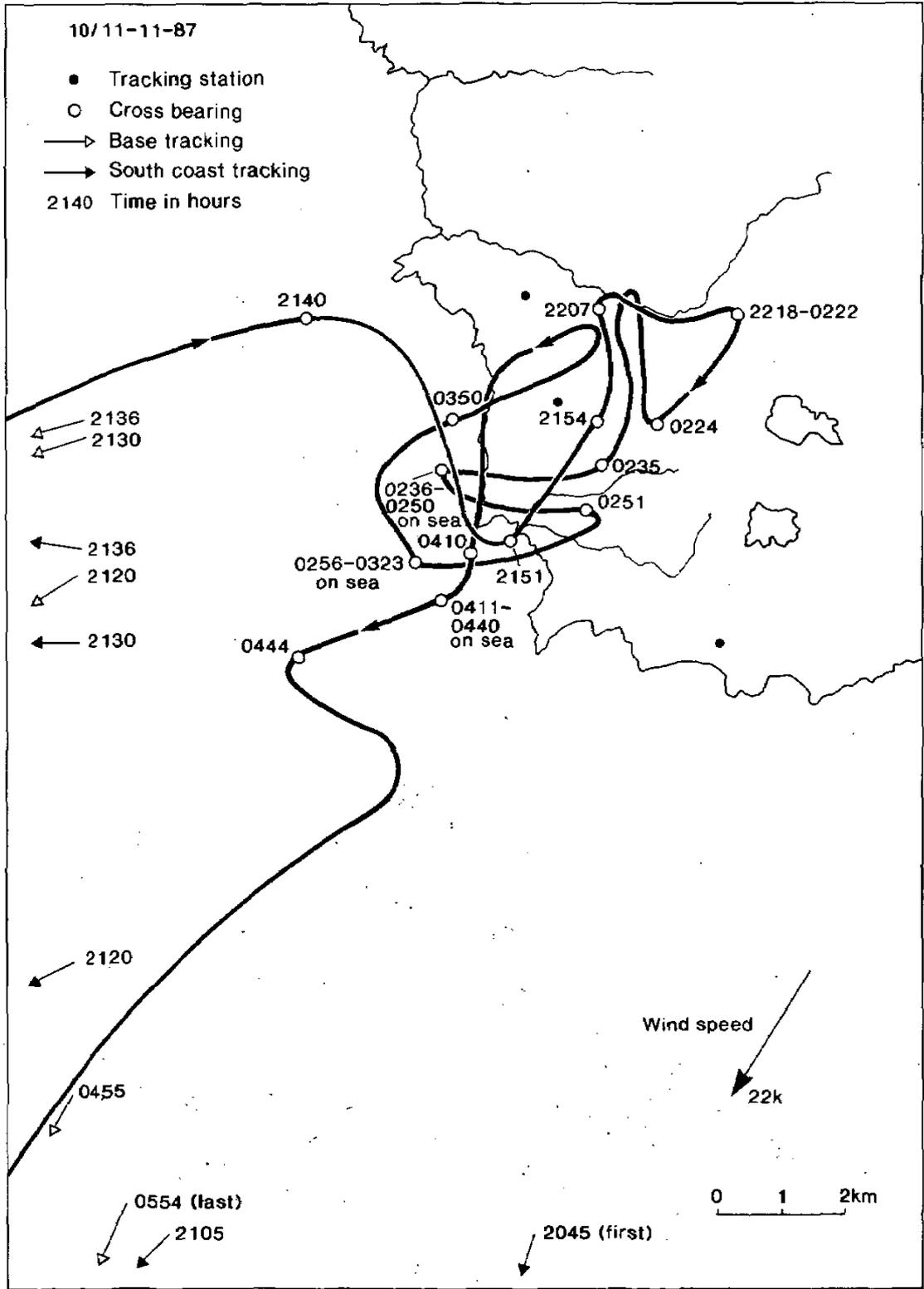


FIGURE 7 – Plots for Taiko that landed by Taiko Stream Valley on 10/11 November 1987. Full darkness at 2159 h.

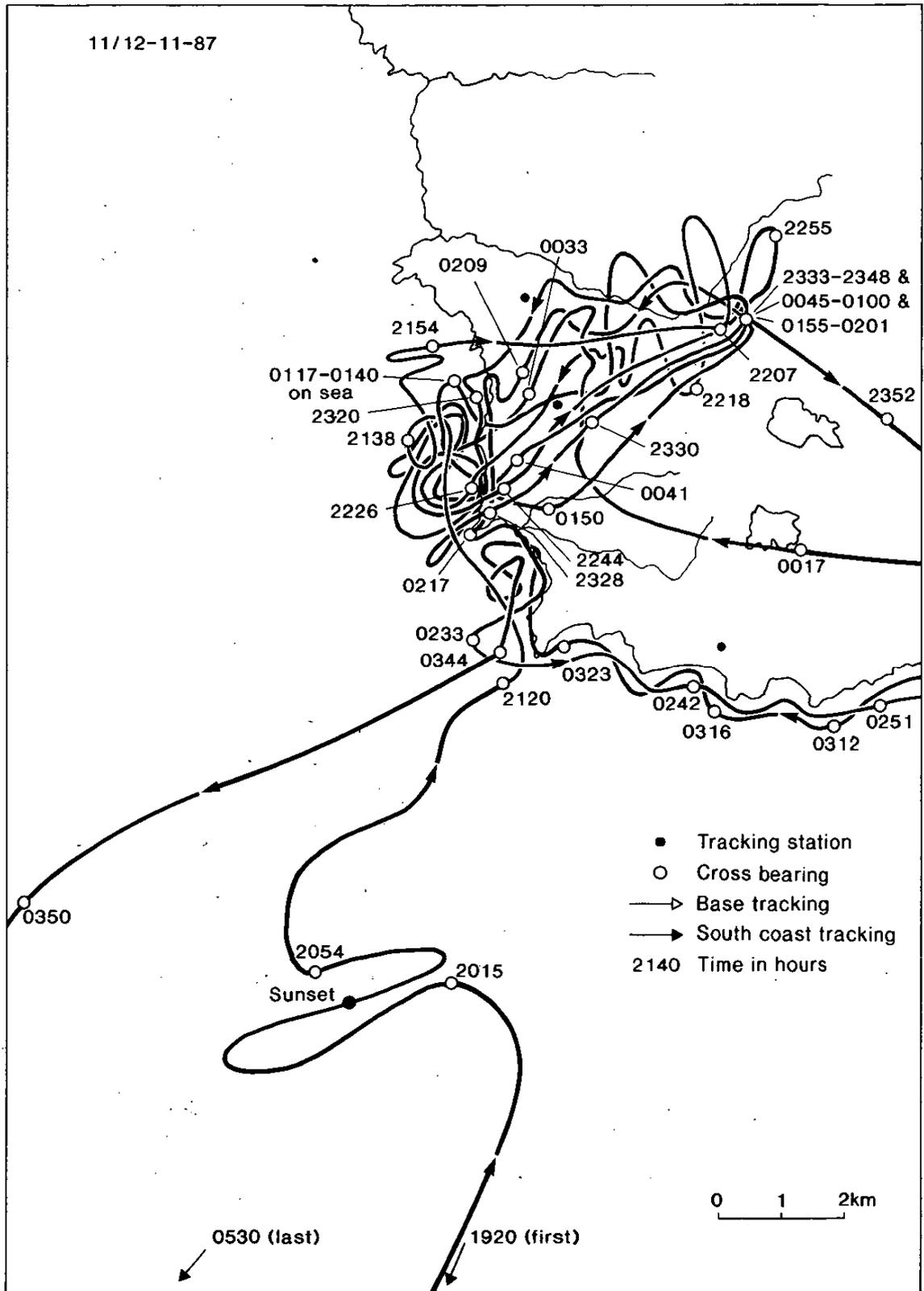


FIGURE 8 – Plots for Taiko tracked on 11/12 November 1987. Full darkness at 2200 h.

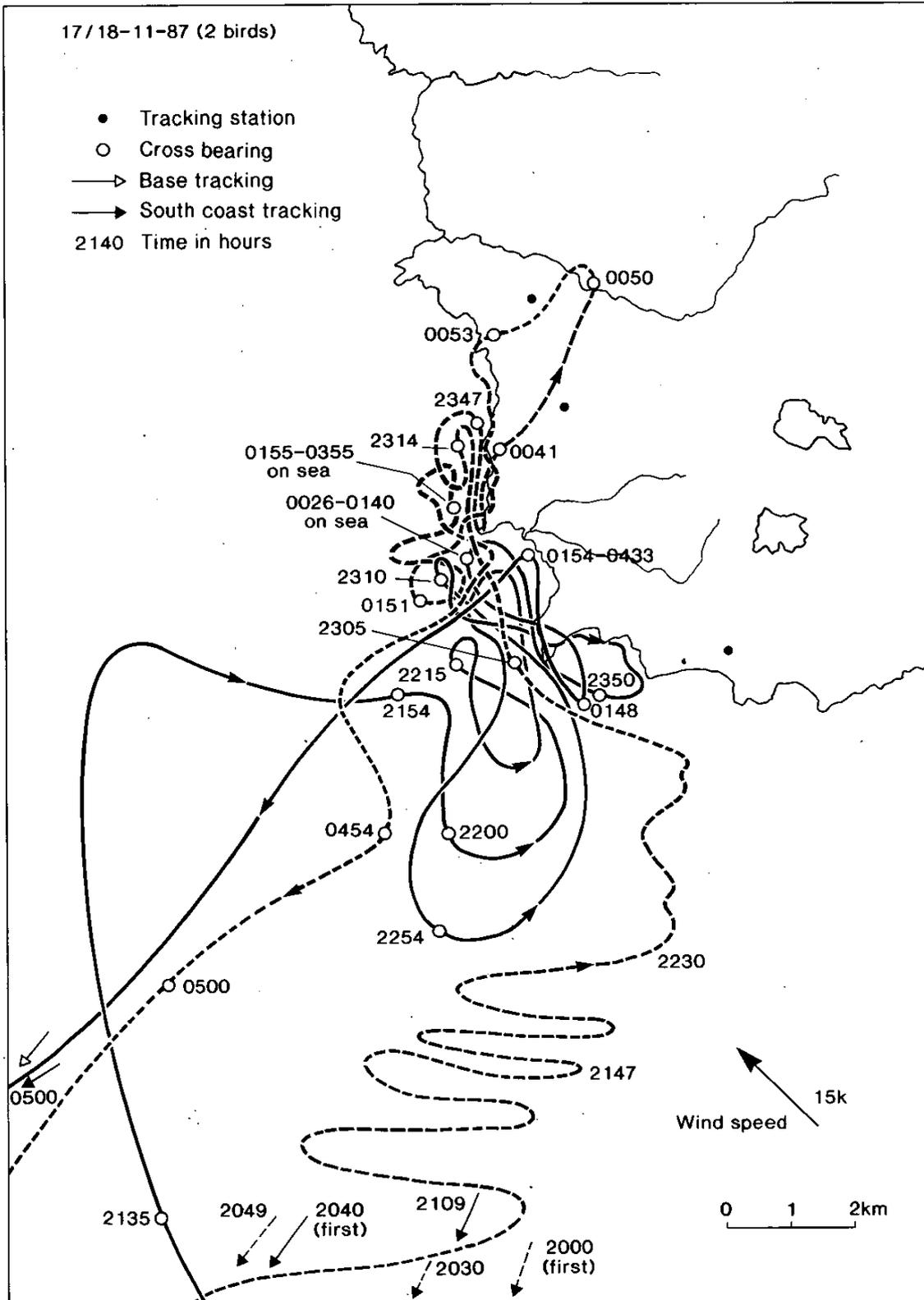


FIGURE 9 – Plots for two Taiko on 17/18 November 1987. Full darkness at 2208 h.

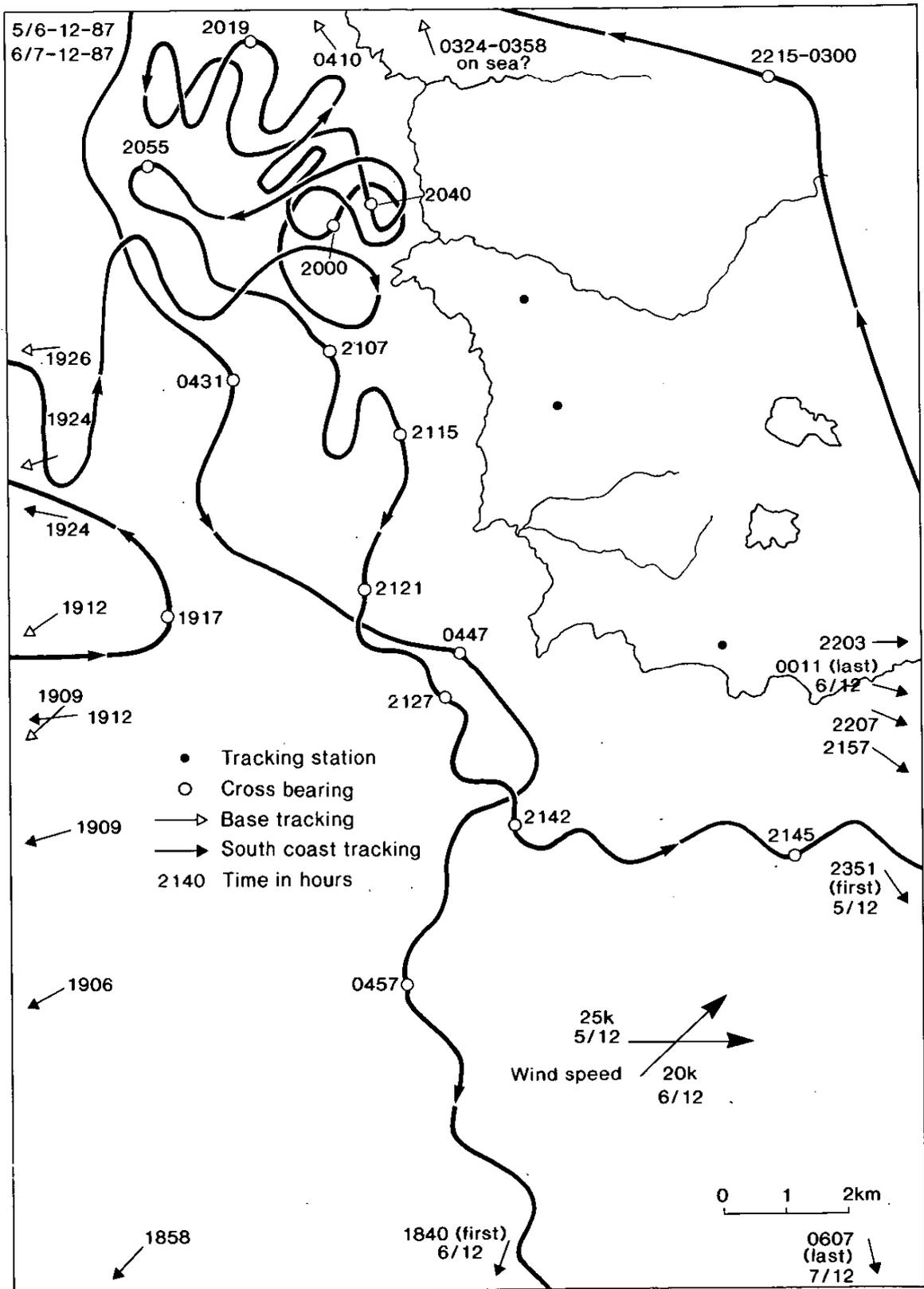


FIGURE 10 - Plots for identifiable Taiko (LR) on 5/6 December, and 6/7 December 1987. Full darkness at 2230 h.

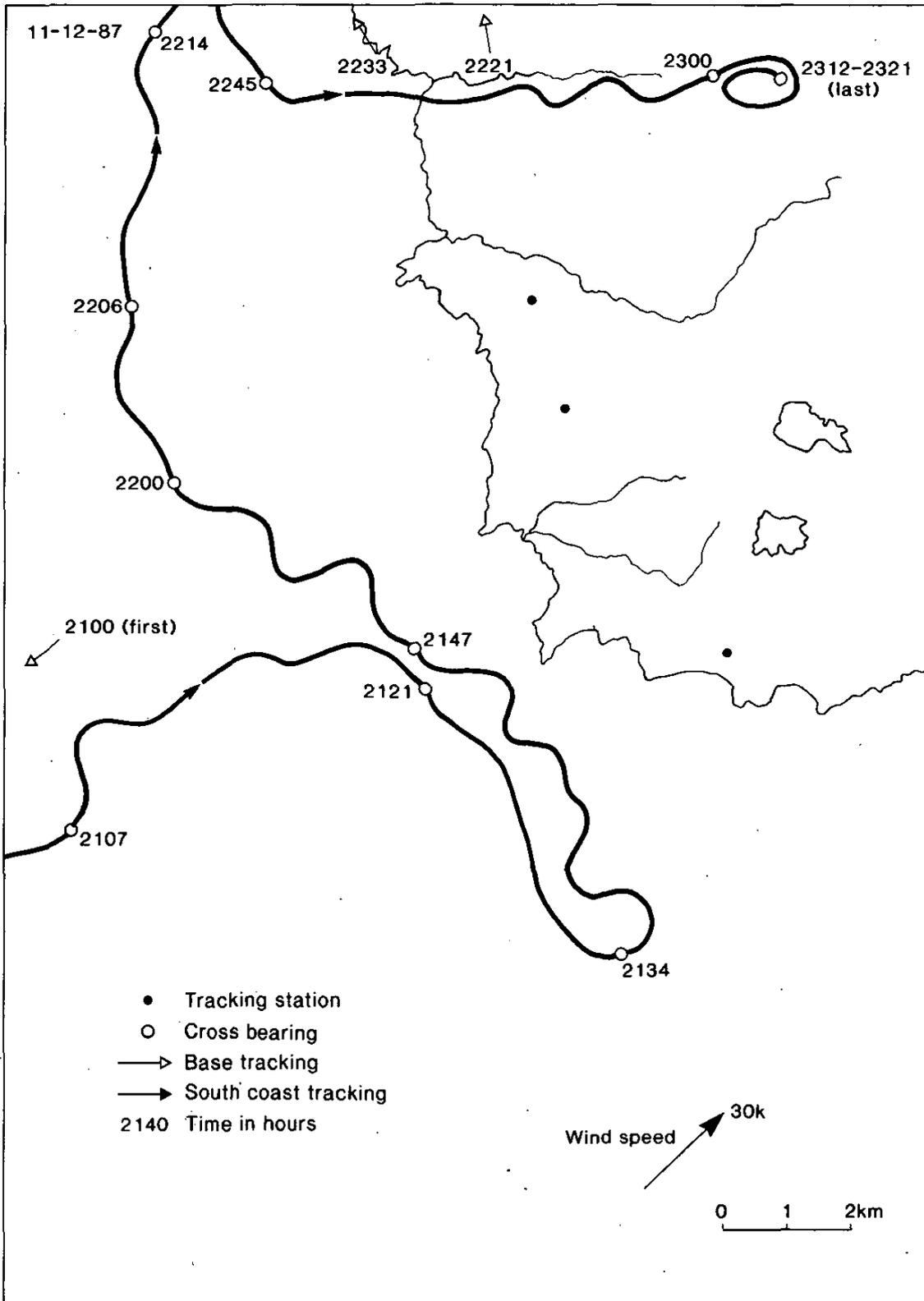


FIGURE 11 – Plots for Taiko LR on 11 December 1987. Full darkness at 2235 h.

entrance. R. Maloney confirmed it to be a Taiko burrow on 24 November when he saw a bird briefly at the entrance at 0125 h. The antenna of a portable receiver was directed at the entrance often, but no signals were detected.

The party searched the catchment until late on 7 November, and again for several days in late November, but found no other burrows. Tuku 1 was about 400 m upstream from the point where the bearing of the stationary Taiko (Oct 20/21, 21/22; Nov 4/5, 10/11) intercepted Taiko Stream. Bearings of a transmitter carried along Taiko Stream Valley, and placed at the burrow mouth were plotted from B and MH on 1 December; the plot differed from that for the stationary Taiko, which appeared to have landed downstream of Tuku 1. Tuku 1 was observed throughout most nights from 18 to 30 November, in an attempt to catch the Taiko occupying it particularly to see if they carried bands – but they were very cautious. A bird was seen twice; each time it entered the burrow immediately. MED made an electronic listening device to alert the attendant to movement at the burrow entrance but extraneous noises (e.g. insects) limited its usefulness. No calls or wingbeats of Taiko were heard during these watches. Common Diving Petrel *Pelecanoides urinatrix* calls were heard once, at 0300 h in light rain.

A search to locate LR after its transmitter became stationary was hampered by a lack of aerial photographs of the area; those then available at Base Camp did not show areas north of the Tuku catchment.

Two very difficult coastal sites were also searched during this period, because it was thought Taiko with transmitters had landed there. Blyth's Stack was reached by wading at low tide on 9 November by G. Murman, G. Taylor and K. Scollay. Nearly all burrowable parts of the stack, including the northern face (by GM using a rope), were searched, but only Broad-billed Prion *Pachyptila vittata* chicks were found. Only one hole seen was large enough for Taiko but there was no sign of their presence. Broad-billed Prions are active at breeding sites throughout the year, and may displace even Sooty Shearwaters from burrows (MJI, pers. obs.), so it is probable that Blyth's Stack was never a regular breeding site for Taiko.

As it was possible that a Taiko had landed on cliffs east of SC on 18/19 October, a close survey of potential cliff ledges for Taiko burrows between Tuku mouth and Cascades Gorge was made from the yacht *Totorore* on 3 December. These cliffs, and those further east, had been surveyed by sea and land many times during the previous decade, but *Totorore* allowed a closer, more detailed inspection. No suitable ledges were seen, which confirmed the results of nine previous explorations, three of which had used ropes to get to ledges, which had together covered the entire southern coast. The most promising site seen from *Totorore* was a vegetated, but narrow ledge well down a 200 m cliff just east of Green Point. R. Mayhill abseiled to this ledge on 5 December but found no burrowable ground. It is now thought that no Taiko with transmitters had actually landed at either site.

April 1988

In early 1988, MJI obtained aerial photographs (taken in 1983) of the entire area of southern Chatham Island still under bush. A small hill was apparent in the area where LR had landed. This hill (since named North Taikill)

does not project above the undulating topography of the surrounding bush, so was difficult to find from the ground until a track was made to it in late 1988, but it stood out in stereo-pair aerial photographs.

A. Plant and MJI searched for North Taiko Hill and burrows on it from 7 to 26 April 1988 when any Taiko fledglings should have been preparing to leave. Taiko Stream Valley and other sites farther inland were also searched. Tuku 1 was found to have been unsuccessful (Imber *et al.* 1994). MJI found a second burrow about 5 m away where digging had occurred recently. This was found to be about 2.5 m long in November 1992, but activity in it had then ceased.

MJI accidentally found a third burrow (Tuku 10) about 400 m downstream from Tuku 1. A large piece of eggshell and feathers were found at the entrance. The eggshell lacked the thickened membranes of a hatched egg, so it was either infertile or had failed early in incubation. By April 11, activity had ceased in Tuku 10 also. This burrow was much closer to the bearing of the Taiko that had been tracked to the valley, and for over two years it was thought to be the burrow involved.

On 15 April North Taiko Hill was reached and searched; AP soon found two burrows about 3 m apart, near its top. One (North 1) appeared to have been in use for decades. The other had recent signs of scratching-out suggesting that it had been used by non-breeders. North Taiko Hill was exactly on the bearing (34°) where LR was briefly monitored from MH on 6 December 1987. Down was found at the entrance to North 1 on 22 April, indicating that a fledgling was inside, but an attempt to catch it that night was unsuccessful.

Other searches elsewhere during this field trip on ridges, headlands and a more extensive hill adjacent to North Taiko Hill, parts of the north slope facing Waitangi, and several hills in the eastern central part of the remaining native bush, in the area called Pipitarawai, were unsuccessful.

Subsequent searches

The failure of the tracking programme during October-December 1988 meant that no further potential burrow sites were located. Further searches for burrows were made, mainly around the known burrows, but without result.

A. Tennyson found another burrow (Tuku 4) about 15 m uphill from Tuku 1 during studies at the Taiko Stream Valley burrows during January-February 1991. The area had been closely searched when Tuku 1 was found, and repeatedly thereafter, so this burrow was probably dug or re-opened about 1990-1991. The small amount of soil ejected from this burrow (> 1 m long) suggested it had been re-opened after a period of disuse.

Extensive, methodical searches for burrows were carried out early in 1992, mainly in the Taiko Stream and adjacent catchment, and at North Taiko Hill and on adjacent ridges, hills and spurs, but no more breeding burrows of Taiko were found. However, another possibly newly-worked burrow was found in the Tuku 1 area; and a partially dug, 1.5 m long, burrow was found on a hilltop about 300 m downstream from Tuku 1. This new

burrow was at the bearing of the Taiko radio-tracked to Taiko Stream Valley in 1987. The burrow had been excavated relatively recently. The hill slopes had been searched before, but not the flat top where the burrow was found. Unfortunately the burrow's entrance seemed to have been dug into by a larger animal (such as a dog or possum), so reducing its length. It appeared to have been abandoned by Taiko.

DISCUSSION

Location of burrows

This was the first time that the breeding sites of a seabird had been found using radio telemetry. The finding of burrows in the hinterland of south-west Chatham Island vindicated the persistence of DEC in concentrating the search in that area over 17 years of "Taiko Expeditions". The suggestion by MJI that Taiko might breed on the lesser Chatham Islands, lost among the multitudes of other petrels, particularly with Sooty Shearwaters – safe from all predators except skuas, but subject to intense competition for burrows – was shown to be much less likely. Data from South Coast station, supplemented by those from Mangere Island and *Totorore*, did not reveal any indication that Taiko with transmitters visited land other than south-west Chatham Island.

Comprehensive searches by Wildlife Service teams of the coastal cliffs and nearby islets and stacks had shown them to be either physically unsuitable for burrowing, accessible to stock and predators, or dominated by one or more of three other breeding species: Broad-billed Prions, Sooty Shearwaters, or Little Blue Penguins *Eudyptula minor*. The Taiko with transmitters spent much time flying near the cliffs during visits to land. Two or three birds apparently landed there for periods of up to an hour, but no bird made the repeated visits that could have indicated a burrow. One of the Taiko that landed could have been attracted to shearwater burrows, now gone. That Taiko do sometimes land near clifftops and so risk being killed by cats, was shown by the remains of one found south of Blyth's Stack in 1982. All remaining active burrows seem to be far inland, scattered under relatively undisturbed forest. In these areas, Taiko are at less risk from domestic and feral stock, and predators, which are more abundant closer to the coast.

Behaviour of non-breeding Taiko

Before transmitters were put on Taiko, many caught at the Tuku light were known to be non-breeders. They were caught when breeders should have been on their pre-laying exodus (estimated to be through November). Only one Taiko had been caught with a weight close to that for a Taiko beginning incubation (cf. Grey-faced Petrels, Imber 1976). The telemetry results confirmed this view, because only two of 10 birds with transmitters landed more than once. Even their behaviour was not that expected of breeders. The bird that visited Taiko Stream Valley went to the burrow more often than would be expected during the time of the exodus, and the one at North Taiko Hill arrived when incubation should be starting, and would not have been expected to leave, then return so soon. Subsequent research has provided overwhelming evidence that the two birds were not breeders.

The tracking results suggested that these Taiko preferred the inshore area from Cape L'Eveque 4 km northwards to west of Murphy's Hill when visiting Chatham Island. All but two of the Taiko that only flew around or landed briefly, or settled on the sea inshore, spent much or most of their visiting time in that area. Of the other two, the bird that landed in Taiko Stream Valley often settled on the sea there, and the bird going to North Taiko Hill flew through that area. This may be the courtship and pair formation area for Taiko, now that the breeding grounds have become so fragmented and scattered.

A common courtship area would maximise the opportunities for unmated birds to make contact with other Taiko, given that this would occur rarely if activities were restricted to the airspace above their widespread natal burrows. The courtship area lies astride the commonest flight paths to the burrows. If birds do use the area in the way hypothesised, it would explain the lack of any observations to date of Taiko heard calling or flying about over the known burrow areas. Remnant burrows of Cook's Petrel *Pterodroma cookii* at Codfish Island are almost as scattered as those of Taiko because of predation by Weka, and the petrels have a courtship area in Sealers' Bay (MJI, pers. obs. 1975-1985).

The tracking results also indicate how infrequently non-breeding petrels may visit the breeding places. Even though 10 transmitters were used, only 16 trackings were obtained. The last was on 11 December but battery life should have allowed transmissions to have continued until at least late January. This is consistent with the marked decline in sightings at the Tuku light after mid-December over many years, and their cessation by late January (the latest capture has been on 11 January). Excluding the eight trackings for the two birds that landed, the other eight Taiko were, on average, each tracked only once. The time of their capture represented another visit, and each may have made earlier visits, but the results showed that the mean period between visits was nine days for the two Taiko that landed, assuming that the transmitters did not affect their routine. Each made only about four to five visits during the entire breeding season.

Post-capture aversion to Tuku light

It was notable that none of the Taiko with transmitters in 1987 went into the beam of the Tuku light, despite its being on nearly constantly. Several tracked Taiko approached the light as if attracted to it (its beam could be seen for >5 km), but then veered away. The failure to catch any Taiko during 308 hours of light operation in 1988 was because the number of uncaptured (unbanded) birds was limited.

Because nine Taiko had been recaptured at the light, but only one twice, it was thought at first that banded and unbanded Taiko were equally catchable – a prerequisite for estimating population size by mark-recapture (Lincoln index). It now seems that the Tuku light operation had been selectively catching unbanded Taiko. The light could be used after 1987 to catch only the few banded Taiko that can be recaptured, and returning young birds on their first exposure to the light.

Feeding range

The Chatham Islands lie at the Subtropical Convergence (Fleming 1939). The consistent arrival of Taiko from south of the Chatham Islands, and departures usually in that direction, but occasionally westwards, revealed that they feed in the subantarctic seas to the south, rather than subtropical seas to the north of the islands. A possible pelagic sighting of Taiko, one of few reported this century, was south of the Chatham Islands (Rogers 1980), but the bird seen may have been a Soft-plumaged Petrel *P. mollis* (see references in Crockett 1994).

CONCLUSIONS

Five Taiko burrows were found in the hinterland of south-west Chatham Island by radio telemetry of returning adults. No Taiko visited other islands in the group, and casual landings on the coast were apparently by birds prospecting for sites. Most Taiko caught at the Tuku light subsequently avoided it. Mark-recapture estimates of population size from such captures were therefore meaningless (cf. Crockett 1994).

All 10 Taiko with transmitters behaved as if they were non-breeders, although two did visit burrows. Non-breeding Taiko visited Chatham Island infrequently, perhaps twice to five times per breeding season. Taiko foraged in the subantarctic seas south of Chatham Islands. A concentration of Taiko activity inshore along 4 km of coast north from Cape L'Eveque indicated a possible pairing and courtship area there.

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