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Re-laying by Hutton's shearwaters (*Puffinus huttoni*) at Te Rae o Atiu, Kaikōura Peninsula, New Zealand

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Abstract: Observations were made of the Nationally Vulnerable Hutton's shearwater (*Puffinus huttoni*) breeding at Te Rae o Atiu, Kaikōura Peninsula (42.429°S, 173.703°E), New Zealand, a new colony established by translocations where birds breed in nestboxes. Over 12 seasons there were 245 eggs laid, including seven instances of two eggs laid as separate clutches in one nestbox during the same season. Nestbox inspections, usually undertaken weekly, provided evidence of egg laying date. Bird attendance at the nestboxes was also obtained from implanted passive integrated transponders that triggered a reader and datalogger. There is evidence for birds re-laying an egg after the first egg failed for three separate events, and a fourth was a possibility. In three other events, it appears more likely that two different birds laid the eggs, two as female-female pairings or simply egg dumping by an unpaired female; the third event was inconclusive. Only one of the 14 eggs from two-egg nests hatched, and the chick fledged successfully, about 10 days later than any other chick recorded at this colony. This fledging date was similar to the last date for fallout birds from the natural, mountain colonies, and suggests that re-laying may be a natural consequence of early egg failures in this species.

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INTRODUCTION

Hutton's shearwater (*Puffinus huttoni*) is a small black and white shearwater (length 36–38 cm; weight 365 g; Marchant & Higgins 1990) currently classified by BirdLife International (2021) as "Endangered", and as "Threatened – Nationally Vulnerable" under the New Zealand Threat Classification system (Robertson *et al.* 2021). The two known remaining natural colonies are found in the upper Kōwhai River catchment (42.261°S, 173.603°E) and at Shearwater Stream (42.167°S, 173.727°E) in the Seaward Kaikōura Ranges, where they are vulnerable to destruction by pigs (*Sus scrofa*) (Cuthbert 2002) and tectonic activity (Cuthbert 2019). On 14 November 2016, for example,

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the 7.8 magnitude Kaikōura earthquake resulted in approximately 12% colony area loss through landslides and a reduction in burrow density of about 29% in the surviving colonies (Cuthbert 2019).

The Department of Conservation (DOC) identified Hutton's shearwater as a species requiring medium-term action for its recovery (Molloy & Davis 1992). An agreement was reached in 2005 between DOC and Whale Watch Kaikōura for a new colony (now called Te Rae o Atiu) to be established on Whale Watch land on the Kaikōura Peninsula (42.429°S, 173.703°E). Chicks were translocated from 2005 to 2013, and there is now (2022–2023 season) a population of 86 birds returning to the site to breed in nestboxes (TH *unpubl. data*). Intensive monitoring at this new, readily accessible colony has provided the opportunity for more in-depth studies.

Shearwaters generally lay one egg without replacement (Marchant & Higgins 1990; Warham 1990), and this is the norm for small shearwaters, e.g. Manx shearwater (*Puffinus puffinus*; Harris 1966; Brooke 1990), Balearic shearwater (*P. mauretanicus*; ACAP 2021), Yelkouan shearwater (*P. yelkouan*; Anon 2020), black-vented shearwaters (*P. opisthomelas*; Keitt *et al*. 2000) and Newell's shearwater (*P. newelli*; FWS 2021; KESRP 2021). This was the case for 231 of 245 Hutton's shearwater eggs laid at Te Rae o Atiu from 2011 to 2022, where re-laying did not occur if an egg failed (LKR, TH *unpubl. data*). However, over 12 seasons, there were seven instances where we found two eggs in a given nestbox at Te Rae o Atiu in the same season. This paper presents information on re-laying and potential female-female pairings by breeding Hutton's shearwaters at Te Rae o Atiu and makes comparisons with observations from other petrel and shearwater species.

METHODS

During the breeding season (late August to April) (Marchant & Higgins 1990), daytime visits were made to monitor activity at the Te Rae o Atiu Hutton's shearwater colony, usually at about weekly intervals. The occasional night-time visit was made as part of other studies. Each bird was banded with a unique-numbered flattened stainless-steel X-band (8.0x3.5 mm) on the tarsometatarsus (tarsus). Passive integrated transponders (PIT-tags) were inserted under the skin at the base of the neck of the 2012 and 2013 translocation chicks, and from summer 2011–12, into returning birds from the 2006 to 2011 translocations, pre-fledging chicks, and any unmarked immigrant adults visiting the new site. Some of the earlier birds were not PIT-tagged until 2015 or later. Readers and dataloggers located on visited nestboxes enabled records to be obtained when birds entered or left nestboxes (for details, see Taylor *et al*. 2012; Rowe 2014, 2018). Readers were not always available on nestboxes to help determine which adults were attending eggs. In the early years, captured adults had Twink™ markings painted either along (|) or across (–) the crowns of their heads to identify birds in a nestbox without having to disturb them repeatedly (Rowe & Howard 2023).

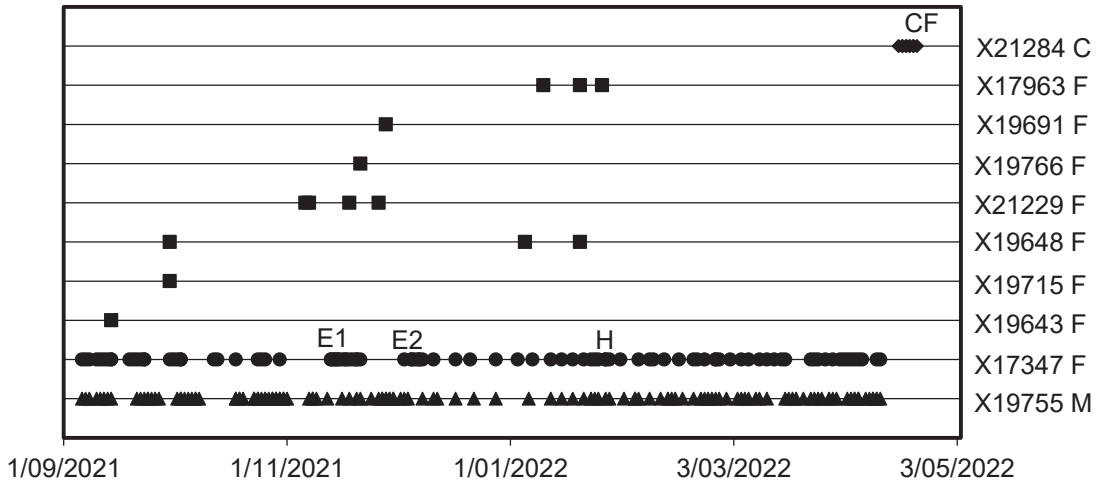

Figure 1. Timelines for Hutton's shearwaters entering and leaving nestbox 97 in 2021–22 (Event A) as recorded by the PIT readers: ▲ = X19755 male; ● = X17347 female; ♦= X21284 fledging chick; ■ = other females. E1 = egg 97/1 first seen and present through January; E2 = egg 97/2 laid about 4 December; H = egg 97/2 hatched about 24 January; CF = date X21284 fledged.

Figure 2. Nestbox 97, 25 December 2021. The egg, probably 97/1, is in the nestbox and an adult bird (X17347 from PIT records) in the rear chamber is incubating egg 97/2. (Photograph: Ted Howard).

Monitoring visits defined the time interval during which eggs were laid. From available PIT records we determined the laying dates as the first night after the cessation of a short pre-laying exodus (PLE). Birds were sexed from DNA analysis of feather samples (Griffiths *et al*. 1998), and where these were not available, they were sexed as breeding partners of known-sex birds.

RESULTS

Event A: Nestbox 97 2021–22

During the 2021–2022 breeding season, birds in nestbox 97 excavated a tunnel about 50 cm deep beyond the incomplete back wall of the nestbox. Egg 97/1 was laid between monitoring visits on 10 and 13 November in the nestbox chamber. Of the eight females known to visit nestbox 97 that season only X17347 was recorded present at the time the egg was laid. PIT records show X17347 followed the general pattern for pre-laying exodus (PLE) and egg laying for Hutton's shearwaters (LKR *unpubl. data*). She left at 0418 h on 30 October and returned 14 days later (13 November at 0041 h) to lay (Fig. 1). This egg was seen in the nestbox chamber later that day, and another seven times when the egg was moved by TH to the bird in the rear chamber (Table 1; Fig. 2). Under normal conditions at Te Rae o Atiu (52 days incubation period, LKR *unpubl. data*), the egg should have hatched about 4 January but was seen in the nestbox chamber until at least 29 January (Table 1), although never incubated.

On 29 January, a 90 g chick was heard then found in the rear chamber. During earlier visits, shearwaters were observed sitting in the back chamber but were not handled. These were either X19755 (male) or X17347 from the associated PIT-tag records (Fig. 1). They were presumably incubating egg 97/2 while the first egg, assumed to be 97/1, was in the nestbox chamber (Fig. 2).

The chick fledged on 22 April, suggesting it would have hatched from egg 97/2 about 25 January when applying the average 87-day fledgling period for Hutton's shearwaters at Te Rae o Atiu (LKR *unpubl. data*). Mass/age plots in Cuthbert (2002) suggest that the 90 g chick would have been about four days old when first seen, again indicating 25 January as the hatching date. The average incubation time of 52 days indicates that the egg would have been laid about 4 December. X17347 arrived back from an extended period away from the nestbox between 0405 h on 21 November and 2224 h on 3

Table 1. Timeline of Hutton's shearwaters observations at Te Rae o Atiu, Kaikōura Peninsula, New Zealand; nestbox 97, 2021–22.

Date	Observation
10 November	No birds or egg
13 November	Egg 97/1 first seen
20 November	Bird in rear chamber; TH moved egg from nestbox chamber to rear chamber
27 November	Bird in rear chamber; TH moved egg from nestbox chamber to rear chamber
11 December	Bird in rear chamber; TH moved egg from nestbox chamber to rear chamber
18 December	Bird in rear chamber; TH moved egg from nestbox chamber to rear chamber
25 December	Bird in rear chamber; TH moved egg from nestbox chamber to rear chamber (Fig. 2)
1 January	Bird in rear chamber; TH moved egg from nestbox chamber to rear chamber
5 January	Bird in rear chamber; TH moved egg from nestbox chamber to rear chamber
15 January	No bird present, one egg in nestbox chamber – not touched; floor of rear chamber not visible
29 January	Chick (90 g) in rear chamber; egg in nestbox chamber
19 April	Chick present; 345 g
22 April	Chick gone = fledged

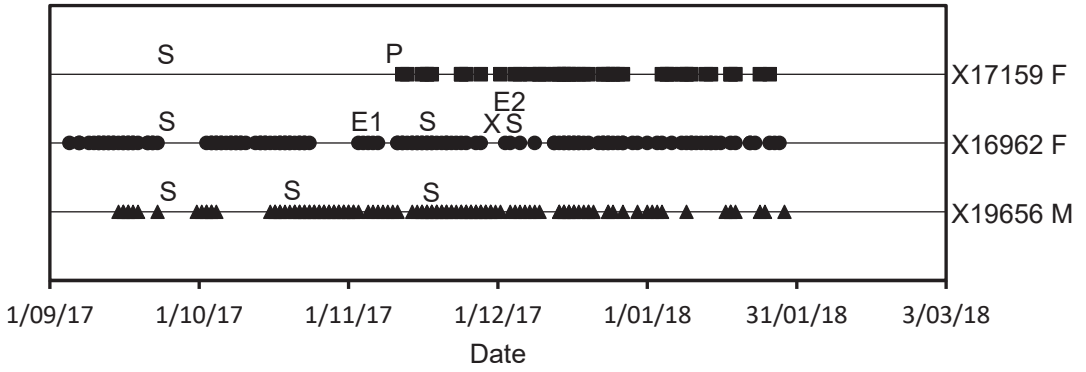

Figure 3. Timelines for Hutton's shearwaters entering and leaving nestbox 21 in 2017–18 (Event B) as recorded by the PIT readers: ▲ = X19656 male; ● = X16962 female; ■ = X17159 female. P = bird PIT-tagged; S = bird seen in nestbox; E1 = egg 21/1 first seen; E2 = egg 21/2 first seen; X = egg 21/1 ejected from nestbox.

December, a total of 13 days. If the return was the end of a PLE, the egg would have been laid before X17347 left the nestbox at 0008 h on 5 December, which corresponds to the time of laying calculated from hatching and fledging dates. There were no other females present on the laying date.

Event B: 2017–18 Nestbox 21

On 24 September three birds, X16962 (female), X19656 (male) and X17159 (female), were seen in nestbox 21 at night. In that same nestbox, egg 21/1 was laid between visits on 1 and 5 November 2017 when a bird was seen sitting on it. X16962 had left on a 10-day PLE at 0511 h on 24 October and arrived back at 2106 h on 3 November. She then laid egg 21/1 before leaving at 0403 h on 4 November (Fig. 3). X16962 was seen sitting on a cracked egg on 18 November, which further suggests she was the female parent. Egg 21/2 was laid between visits on 1 and 5 December when X16962 was seen incubating the egg. Having returned from a six-day PLE starting 0443 h on 28 November to 2210 h on 3 December (or nine days starting 0450 h on 25 November if a short visit on the night of 27 November is ignored), X16962 would have laid egg 21/2 before leaving at 0305 h on 4 December, 31 days after 21/1 was laid. Egg 21/1 was ejected from the nestbox between visits on 30 November and 5 December by X19656(?) before egg 21/2 was laid.

There are no PIT records for X17159 which was seen with X16962 and X16956 in September until she was PIT-tagged on 12 November. Therefore, we do not know what her status was when 21/1 was laid. During the interval egg 21/2 was laid X17159 was only present at 0211 h to 0220 h on 2 December, a 9-minute visit. It seems implausible that she could have laid an egg and departed in this very short interval. The available PIT records did not show she had any extended absences greater than three days prior to 2 December that could be construed as a PLE. X19656 was the only male frequenting nestbox 21 on a regular basis.

There were no PIT records for any other females at this nestbox when egg 21/2 was laid and we believe all birds were PIT-tagged at that time.

Event C: 2012–13 Nestbox 99

Egg 99/1 was laid between visits on 28 October and 1 November 2012 when X16995 was seen sitting on it; this was the first observation of a bird in the nestbox although it had been visited most weeks from 3 September. On 1 November a PIT-tag reader was installed on nestbox 99 and X16995 was PIT-tagged. It is assumed X16995 laid egg 99/1 as she continued to incubate it (Fig. 4). X16912 (male, PIT-tagged 7 November) was seen sitting on the egg on 7 November and is, therefore, likely to be the second parent. No other PIT-tagged females were recorded, although it is likely untagged birds were present at Te Rae o Atiu. On 7 November, egg 99/1 was found stuck to the brood patch of X16912, was detached by LKR and left in the nestbox. When nestbox 99 was visited on the morning of 10 November, no birds nor egg were found. The egg may have cracked, leaking its contents and, presumably, removed from the nestbox by one of the partners.

Monitoring visits to nestbox 99 found egg 99/2 was laid between visits on 23 and 29 November. PIT records show X16955 was absent from 0350 h on 10 November to 2208 h on 24 November, a possible 15-day PLE, and probably laid the egg before leaving again at 0403 h on 25 November. No other PIT-tagged females were recorded at that time. Thus, X16995 could have laid egg 99/1 before 1 November and egg 99/2 on 24 November, about 26 days apart. The female had a continued presence until 24

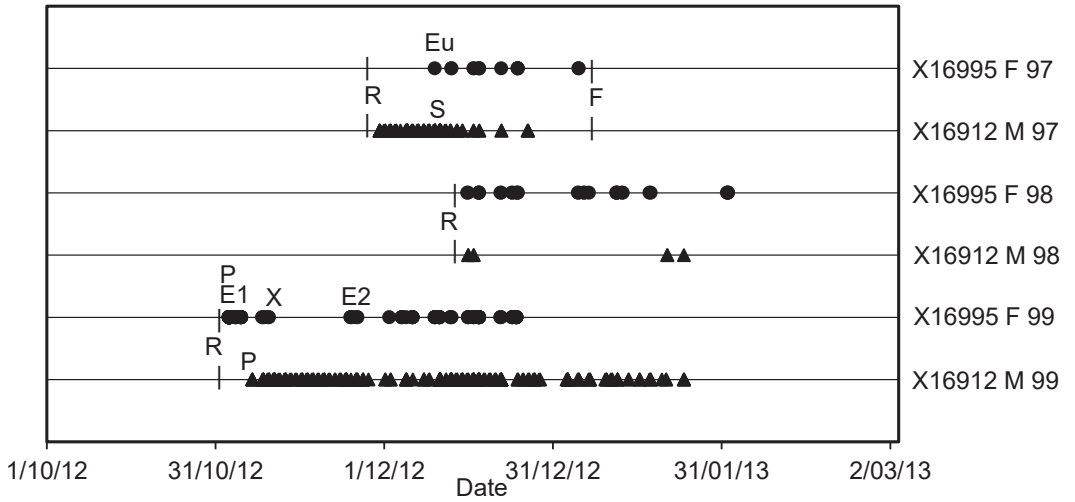

Figure 4. Timelines for Hutton's shearwaters entering and leaving nestboxes 97, 98 and 99 in 2012–13 (Event C) as recorded by the PIT readers: ▲ = X16912 male; ● = X16995 female. R = start of PIT-tag record; F = finish of PIT record; P = bird PIT-tagged; S = bird seen in nestbox; E1 = egg 99/1 first seen; E2 = egg 99/2 first seen; Eu = egg 97/1 first seen; X = egg 99/1 ejected from nestbox.

December and the male until 24 January; the egg was noted as broken on 28 December.

In addition to these activities in nestbox 99, X16955 and X16912 were recorded by PIT-tag readers, but not seen, at nestboxes 97 and 98 later in the season.

Event D: 2012–13 Nestbox 38

The timeline for events at nestbox 38 in which two eggs were laid is shown in Fig. 5. On 11 October, X15960 (male, Twink™ |) and X17152 (female Twink™ –) were seen together in nestbox 38 in the daytime, inferring they may have been a pair; they were then PIT-tagged. The same pair also spent considerable time in nestbox 37, where another egg was laid (Fig. 5); the female that laid that egg is unknown.

Egg 38/1 was laid between monitoring visits on 7 and 10 November. From PIT records, we infer X17152 left on a seven-day PLE at 0423 h

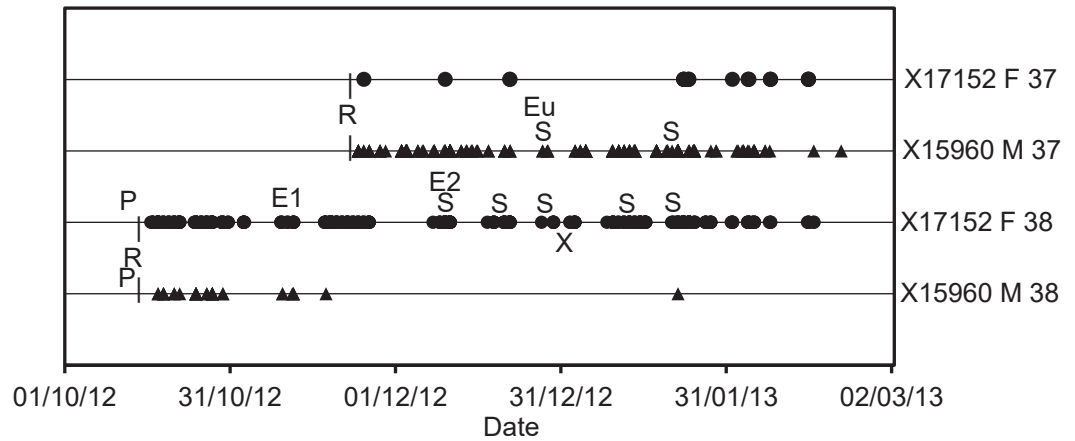

Figure 5. Timelines for Hutton's shearwaters entering and leaving nestboxes 37 and 38 in 2012–13 (Event D) as recorded by the PIT readers: ▲ = X15960 male; ● = X17152 female. R = start of PIT-tag record; P = bird PIT-tagged; S = bird seen in nestbox; E1 = egg 38/1 first seen; E2 = egg 38/2 first seen; Eu = egg 37/1 first seen; X = egg 38/1 ejected from nestbox 38.

on 3 November and arrived back at 2129 h on 9 November. Egg 38/1 would have been laid before she left the nestbox at 0459 h on 10 November. At the time of egg laying, there were no indications of other PIT-tagged females having visited the nestbox, but it is likely there were untagged birds present at Te Rae o Atiu. The egg was unattended during all monitoring visits until 10 December when, based on Twink™ marks on its head, X17152 was in the nestbox at 1140 h sitting next to the egg.

At the next check on 15 December, two eggs were in the nestbox. No females apart from X17152 were seen or recorded in nestbox 38 from 10 to 15 December. It is probable that X17152 was sitting on the second egg, 38/2, on 10 December (she was not picked up to check her band number), with 38/1 seen in the open. In that case, egg 38/2 would have been laid between visits on 1 and 10 December. PIT records show X17152 would have been on a PLE from 0412 h on 26 November and arrived back at 2206 h on 7 December (12 days). She would have laid the egg before leaving at 0337 h on 9 December. She then returned at 0016 h on 10 December to be seen incubating 38/2 during a morning nestbox check while sitting next to egg 38/1. Egg 38/2 was laid 29 days after egg 38/1.

No other PIT-tagged females were recorded at nestbox 38 between visits on 1 and 10 December except for one record of X15943 from nestbox 39 at 2326 h on 2 December. She probably entered the lower end of the tunnel, moved up far enough to get recorded by the logger and backed out immediately. Apart from X17152 present on the night of 11 December, no PIT-tagged females were recorded present between visits on 10 and 15 December. X17152 was seen with two eggs several times until 28 December and then with one egg, 38/2, until 21 January when that egg was noted as not viable. The egg ejected from nestbox 38 between visits on 28 December and 5 January was 38/1 based on size measurements.

Events at adjacent nestbox 37 introduced some complications to events at nestbox 38. X15960 seems to have divorced X17152 in mid-November when he became a regular visitor at nestbox 37, perhaps with an untagged female. An egg, 37/1, was laid there between visits on 23 and 28 December (the latest lay date by 13 days at Te Rae o Atiu [LKR *unpubl. data*]), but apart from three sporadic visits by X17152 up to 22 December, there is no evidence of females being present at the time of laying. Therefore, it must have been a female without a PIT-tag. X15960 was seen on egg 37/1 on two occasions (Fig. 5).

Event E: 2014–15 Nestbox 76

PIT-tag records show two females, X17347 and X16995, frequenting nestbox 76 from mid-September (Fig. 6). Nestbox observations indicated egg 76/1 was laid between visits on 28 October and 4 November. X16995 was absent from nestbox 76 from 0440 h on 24 October to 2135 h on 3 November (11 days) and left again at 0425 h on 5 November. X16995 was sitting on the egg when checks were made on 4 November and is considered the likely female parent of egg 76/1, although X17347 had been present much of the week before 4 November.

The nestbox check on 13 November found two eggs in the nestbox. Therefore, 76/2 was laid between visits on 4 and 13 November. X16995 had been present most days since 4 November. Meanwhile X17347 had been away from 0453 h 2 November for seven days on what may have been a PLE, returning at 2141 h on 8 November to potentially lay egg 76/2 before leaving at 0419 h on 9 November. This was only five days after 76/1 was laid. No birds were seen on subsequent visits, and there is no PIT-tag evidence of these birds frequenting the nestbox after 15 December, an exception being a 1-night visit by X16995 in early February. The eggs were present until late January, at least, and did not hatch. No other PIT-tagged females were recorded

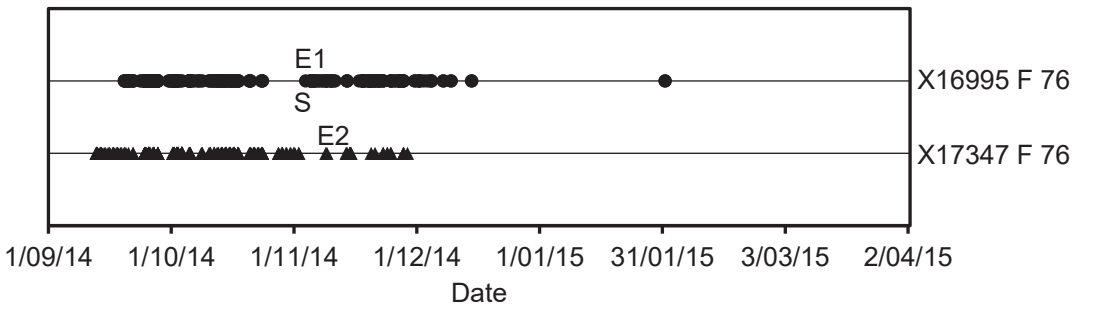

Figure 6. Timelines for Hutton's shearwaters entering and leaving nestbox 76 in 2014–15 (Event E) as recorded by the PIT readers: ▲ = X17347 female; ● = X16995 female. S = X19665 seen in the nestbox; E1 = egg 76/1 first seen; E2 = egg 76/2 first seen.

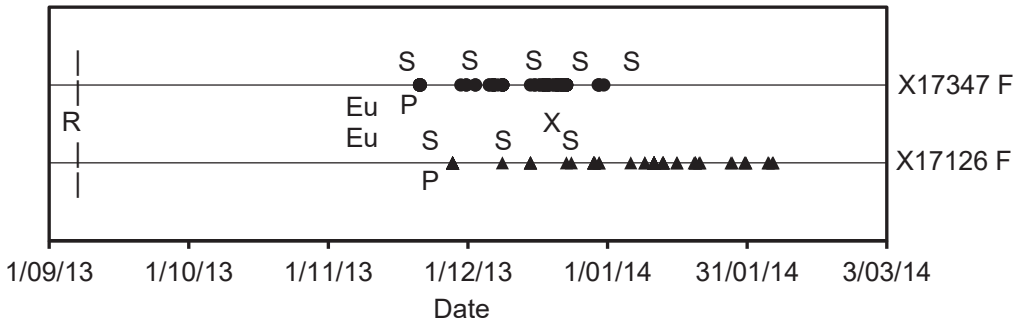

Figure 7. Timelines for Hutton's shearwaters entering and leaving nestbox 11 in 2013–14 (Event F) as recorded by the PIT readers: ▲ = X17126 female; ● = X17347 female. R = start of PIT-tag record; P = bird seen and PIT implanted; S = sightings based on head markings; Eu = egg first seen but unattributable to a given female; X = an egg ejected from the nestbox.

at nestbox 76 about the times the eggs were laid. No PIT-tagged males had a significant presence recorded at this nestbox.

Event F: 2013–14 Nestbox 11

A PIT-tag reader was installed at nestbox 11 on 13 September as there was evidence of birds visiting there. Before 11 November, no birds were seen, nor were there any PIT-tag records of females in this nestbox. However, females X17347 and X17126 may have been frequenting this nestbox prior to this date as they were not PIT-tagged until 20 and 25 November, respectively. Two eggs were seen in this nestbox on 11 November (Fig. 7), there being none on 5 November. Both females were seen sitting on two eggs initially, then one after an egg was ejected between visits on 16 and 20 December; X17347 was on a cracked egg on 6 January. Once females X17347 and X17126 had PIT-tags implanted, they were recorded sporadically at nestbox 11 until February. X17126 was only recorded at nestbox 11, whereas X17347 was recorded occasionally at eight other nestboxes later in the season. Apart from X17124 (male, PIT-tagged 10 November 2012) recorded once only on 22 September, no other birds were seen or recorded from nestbox 11. At the beginning of this season, there were males and females present at Te Rae o Atiu that were not PIT-tagged.

Event G: 2015–16 Nestbox 38

X15990 (male) was seen in nestbox 38 on 16 November. The first of two eggs found in this

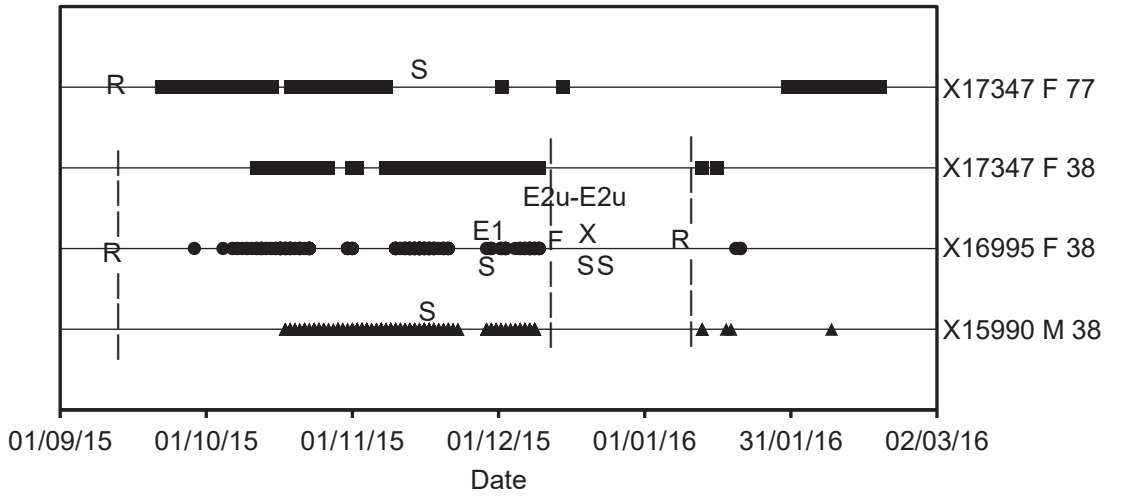

Figure 8. Timelines for Hutton's shearwaters entering and leaving nestboxes 38 and 77 in 2015–16 (Event G) as recorded by the PIT readers: ▲ = X15960 male; ● = X16995 female, ■ = X17347 female. The PIT record at nestbox 38 failed on 10 December through 5 January. R = start of PIT-tag record; F = end of record; S = bird seen in nestbox; E1 = egg 38/1 first seen; E2u–E2u = date range of egg 38/2 laid by unknown female; X = egg 38/1 ejected from nestbox.

nestbox was laid between visits on 23 November and 8 December (Fig. 8). X16995 (female) was seen on egg 38/1 on 8 December and is likely to have laid it after returning at 2158 h on 29 November from a 9-day PLE starting at 0440 h on 21 November. Egg 38/2 was laid between inspections made on 8 and 14 December; no birds were incubating the two eggs on this date. Neither X16995 nor X17347, the other female who had been regularly recorded at nestbox 38, showed the start of an obvious pre-laying exodus before 10 December when the PIT recorder failed. Egg 38/2 would have been laid 10–14 days after egg 38/1 was laid. X16995 was incubating egg 38/2 on 18 December when egg 38/1 was found outside the nestbox, and on 21 December. No birds were seen incubating after 21 December; consequently, neither egg hatched.

DISCUSSION

We are confident that during this study all Hutton's shearwater breeding adults at Te Rae o Atiu were banded. All except two of these breeders were translocated as chicks or were Te Rae o Atiu bred chicks. In the period 2006–2022, only two unbanded immigrant birds have been found at Te Rae o Atiu and both were captured and banded (Rowe & Howard 2023); one of these (X17347) is part of this study – Events A and G. While monitoring undertaken by members of the Hutton's Shearwater Charitable Trust checked birds in nestboxes in daytime, there is a possibility we may have missed birds that were present at night-time. However, several studies from 2014–15 onwards entailing the use of GPS trackers and Time-Depth recorders required night-time visits to capture adult birds provisioning chicks – no unbanded birds were found during that work.

All birds that were not chicks in the 2012 and 2013 translocations or were bred at Te Rae o Atiu have been PIT-tagged as found. Since 2015 we believe all breeding adults have been tagged.

Te Rae o Atiu has 108 nestboxes in place and at 2020–2021 there were 33 breeding pairs present (Rowe & Howard 2023). Thus, there is little competition for nesting sites and no need for multiple pairs to simultaneously use a given nestbox. Up until 2014 there was a sex imbalance with a shortage of males (Rowe & Howard 2023).

Successful relaying Event A

Of the seven events where two eggs were found in a nestbox, Event A has the strongest case for successful re-laying. The only female with a presence throughout the season was X17347. She underwent a PLE leading up to the laying of the first egg and, again, prior to the estimated laying date of the second egg about 22 days later. PIT-tag records did not show any other females present at the time the eggs were laid. PIT-tag records show X19755 was the likely male in attendance and has paired with X17347 for four seasons; single chicks fledged from nestbox 97 in 2019–20 and 2020–2021 but their egg in 2018–19 did not hatch (LKR *unpubl. data*). The egg 97/2 was, therefore, most likely a re-laying after 97/1 was ejected from the rear nest chamber where the adults were incubating 97/2.

Warham (1990) cites studies with circumstantial evidence of re-laying. He also notes many studies have nests with two eggs, but these are likely eggs from two females under the following situations: a) a male with two females forming a trio; b) two pairs trying to use one nest; c) a bird that deserts exposes the egg and allows a second female to lay (dump) hers. There is no evidence to show that situation (a) might have occurred as there is no record of females other than X17347 having a significant presence. Less than 40% of the nestboxes here were occupied in any season, so there was no need for competition for a nestbox and situation (b) does not apply. As X17347 and her mate continued to incubate an egg and fledge a chick then situation (c) is unlikely. Harris (1966) detailed one case of a Manx shearwater repeat-laying after a failure; the second egg also failed. He considered this to be an instance of one female laying eggs by two different mates, but this situation is unlikely in this event. Also, working with Manx shearwaters, Brooke (1990) found re-laying in only one of 77 nestings. Re-laying has been recorded in several species of storm petrels (Morse & Buchheister 1979; Boersma *et al*. 1980) and, more recently, in common diving petrels (*Pelecanoides urinatrix*) (Taylor & Miskelly 2007). Until Event A in this current study, there had been no evidence that re-laying of a second egg has succeeded in producing a fledged chick in larger petrels and shearwaters.

Chick X21284 is the only one from a two-egg nestbox at Te Rae o Atiu to have hatched. It fledged on 22 April (Fig. 1). This fledging date is very late in the season, 12 days later than any others at Te Rae o Atiu (LKR *unpubl. data*). It is also at the later extreme for 682 fallout birds found and banded in Kaikōura; 99% were found by 9 April and the last on 23 April (LKR *unpubl. data)*. Harris (1966) suggested very late fledging Manx shearwater chicks could be due to egg replacements. That is possible here as shown by X21284.

Unsuccessful relaying Events B and C

Nestbox 21 in 2017-18 has a plausible case for re-laying by X16962. She had only three absences greater than nine days which could be construed as PLEs. The first was in September/October which was much earlier than egg laying occurs at Te Rae o Atiu. The timing of the other two absences were

immediately prior to an egg being laid and could, therefore, be considered PLEs. All other absences were less than four days, much shorter than average PLEs for Hutton's shearwaters, 12 days (LKR *unpubl. data*). While X17159 was present all season, after PIT tagging it was not absent for an interval that could be considered a PLE prior to egg 21/2 being laid. Warham's (1990) situation (a), one male with two females, could apply but there is no evidence for X17159 undertaking a PLE and egg laying whereas X16962 does twice at the appropriate times. Thus, the second egg is likely to be a re-laying by X16962 after the failure of egg 21/1.

The second instance of failed relaying, nestbox 99 in 2012-13, was also a case of the second egg, 99/2, was being laid after female X16965 returned from a PLE, 26 days after egg 99/1 was laid and then lost. Again, it is unlikely that any of Warham's (1990) situations apply to this nesting.

Potential relaying Event D

Event D presents a good case for re-laying based on PLEs 29 days apart by X17152 and the estimated laying dates falling into the observed periods. Why a bird would re-lay while the first egg is still in the nestbox (it was not ejected until about 13 days after 38/2 was laid) and her partner had moved to an adjacent nestbox about 22 days before 38/2 was laid questions the assumptions made here. Did a female without a PIT-tag lay one egg?

Female-female pairing Events E and F

Event E did not have any records of males at nestbox 76, only two females from mid-September to mid-December. We believe that by this date in the 2014–15 season, all birds would have been PIT-tagged and the likelihood of an un-tagged male being present is small. Therefore, we are likely to have a female-female pairing with both laying in the same box within four or five days. This may have been driven by the sex imbalance; birds seen or recorded by PIT loggers this season were 21 females and 11 males which produced 16 eggs and eight hatched (LKR *unpubl. data*). There is very little evidence from the literature that female-female pairs form in burrowing seabirds (Bried *et al*. 2009). Still, the strong female pair bonds that formed at the Kauwahaia Island flesh-footed shearwater (*Ardenna carneipes*) colony (Taylor 2024) were most likely created by a shortage of male shearwaters (GT *unpubl. data*), as has been observed in other seabirds (Nisbet & Hatch 1999).

Event F also had two eggs laid within a few days in nestbox 11. In the absence of male records at this nestbox, we suspect this could be another female-female pairing or it was simply two females producing an egg each and dumping their eggs in this nestbox. Both females, X17347 and X17126, incubated the eggs over a six-week period which suggests they had formed a pair bond in that season. Of birds known to be at Te Rae o Atiu either from PIT-tag records or seen, there was a sex imbalance favouring 21 females to 11 males for 15 eggs of which eight hatched (LKR *unpubl. data*). In 2014–15 and later years, both birds were with male partners in separate nestboxes.

Possible Trio Event G

Event G had two females frequenting the nest box over several months together with one male. While it is clear that X16995 laid egg 38/1, we have no evidence as to who laid egg 38/2. It seems implausible for X16995 to have laid egg 38/2 given that she had to recognise that there had been a failure, and then progress to laying the second time. She was seen incubating 38/2 after 38/1 was ejected, suggesting she was the parent. We have two females, X16995 and X17347, who could have laid the eggs but X17347 was not seen incubating them. The missing PIT-tag record means re-laying is not conclusive but we could have Warham's (1990) situation (a) with one male and two females forming a trio.

Implications of re-laying and late departures

Some Hutton's shearwater fledglings on their first flight from the inland natal colonies to the sea get attracted to lights in the Kaikōura township (Harrow 1965, 1976; Deppe *et al*. 2017). Dates of fallout events should encompass the range of fledging for chicks from single egg clutches and any re-laying attempts. The last date of 682 fallout birds that have been found and banded in Kaikōura is 23 April (LKR *unpubl. data).* Chick X21284 is the only one from a two-egg nestbox at Te Rae o Atiu to have hatched and it fledged on 22 April (Fig. 1). This late fledging date supports Harris's (1966) suggestion that very late fledging Manx shearwater chicks could be due to egg replacements. Possibly other very late departing chicks found in previous years could be from replacement eggs as the average fledging date at Te Rae o Atiu is 23rd March, and 95% of chicks fledge within the period 14 March to 1 April.

At Te Rae o Atiu, 95% of eggs are laid before 23 November, and only seven eggs have been laid in December (LKR *unpubl. data*). These seven include probable re-layings: Event A, egg laid 4 December, and chick X21284, the only one from a two-egg nestbox at Te Rae o Atiu to hatch, fledged on 22 April (Fig. 1); Event B egg laid 3 December, with a potential fledging date of 21 April; and Event D egg laid 7 December which had a potential fledging date of 25 April.

There were two other eggs laid very late at Te Rae o Atiu that are well outside the normal pattern of laying in this species and they could potentially have fledged chicks much later than known birds. Brooke (1990) suggested that Manx shearwaters would only lay when there was a chance of a successful outcome and that late egg replacements would fledge late with a low probability of survival. Event G with the second egg laid 11 December might have fledged on 29 April, 6 days later that the last recorded fallout bird. The latest known laying date in this species at Te Rae o Atiu was 25 December, with a potential fledging date of 15 May. The question with this laying is why would a bird lay this late in the season when there was a low probability of fledgling survival, and most fledglings would have gone seven weeks earlier and the colony would be largely deserted by the beginning of April?

While no instances of re-laying in Hutton's shearwaters at the two remaining mountain colonies have been reported, this may be a consequence of limited viewing opportunities and difficulties accessing nest chambers in natural burrows, which are up to two metres long and twist in all directions. Artificial burrows with access through removable wooden lids, as we use at Te Rae o Atiu, and equipped with PIT-tag recorders provide greater opportunities for observing these unusual events.

The ability of Hutton's shearwaters to re-lay might be a local adaptation to the extreme environment in which they normally breed. The Seaward Kaikōura Ranges rise to 2,600 m a.s.l. within 25 km of the coast and are covered in snow during most winters. The extant inland colonies of Hutton's shearwaters range from 1,200 to 1,800 m a.s.l. (Marchant & Higgins 1990). The snow cover on south-facing slopes reduces at a variable rate across these colonies in early spring, and access to nests can be delayed by one or more months on the upper slopes by hard-packed snow and ice cover (Harrow 1976). It is possible that birds could mate in a burrow and then be unable to access the nest chamber when they return from the pre-laying exodus because of an unseasonal dump of fresh snow. If the egg is then dropped at sea or on the land, perhaps the female immediately begins to form a second egg to allow another attempt at laying in the same season. This might explain why Hutton's shearwaters at Te Rae o Atiu are showing more evidence of re-laying a second egg than comparable-sized petrels and shearwaters (Warham 1990), but it might simply be a consequence of the detailed monitoring being undertaken.

In summary, we believe we have one excellent case for a Hutton's shearwater re-laying after an egg failure and fledging a chick (Event A), two further cases for re-laying in which the eggs did not hatch (Events B and C), a probable re-laying (Event D), two cases for female-female pairings (Events E and F), and one inconclusive event that may be a trio (Event G).

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