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# A CROSS-FOSTERING EXPERIMENT BETWEEN THE ENDANGERED TAKAHE (*PORPHYRIO MANTELLI*) AND ITS CLOSEST RELATIVE, THE PUKEKO (*P. PORPHYRIO*)

**Summary:** New Zealand's avifauna is characterised by a variety of endemic, often flightless, birds most of which are critically endangered. One of these, the takahe, is a large flightless rail which has been reduced to one population of 115 birds in its natural alpine habitat plus 52 others introduced on four small offshore islands. By contrast the takahe's closest extant relative, the pukeko, has been highly successful since its invasion of New Zealand within the past 800 years. This paper summarises results of a pilot study in which takahe eggs were cross-fostered to pukeko nests on Mana Island in order to increase the number of juveniles produced by each pair of takahe. Over two seasons, 67% (8/12) of the cross-fostered eggs hatched successfully with 25% (2/8) of the resulting young surviving to one year of age. These results were not significantly different from 42% (5/12) and 40% (2 /5) hatching and fledging success of takahe-reared eggs from the same clutches. Low fledging success of cross-fostered chicks may reflect poor quality of takahe eggs per chicks rather than poor parental care by the pukeko foster parents, as hatching success of all parent-reared takahe eggs on Mana Island was only 22% (5/23) over the course of this research.

**Keywords:** takahe; pukeko; purple swamphen; *Porphyrio mantelli*; *Porphyrio porphyrio*; cross-fostering; conservation; New Zealand.

## Introduction

The takahe (*Porphyrio mantelli* Owen) is a large, flightless rail endemic to New Zealand. The takahe was thought to be extinct until its rediscovery in Murchison Mountains, Fiordland in 1948 and despite intensive management it is still among the most highly endangered avian species in the world. According to the most recent estimate, the takahe population consists of 115 adult birds in Fiordland's isolated alpine habitat, as well as 52 others living on four small offshore islands that are free of introduced mammalian predators (Torr, Eason, and Carroll, 1995).

Competition with introduced deer for snow tussock (*Chionochloa pallens*) has been cited as the principal cause of takahe decline since their rediscovery (Lee, Mills, and Lavers, 1988; Mills, Lee, and Lavers, 1989). However, recent trends in the takahe population indicate that other factors, such as the extremely harsh nature of Fiordland's climate and susceptibility to introduced mammalian predators, also contribute to declines in takahe numbers (Bunin and Jamieson, 1995; Clout and Craig, 1995). In addition, birds released on offshore islands have been plagued with low hatching success relative to Fiordland birds despite the lack of predators and more benign climate (Bunin, Jamieson, and Eason, *in press*). As a result, island populations have not increased as quickly as was expected.

Formerly placed alone in the genus *Notornis*, it is now accepted that takahe are very close relatives of pukeko or purple swamphens (*Porphyrio porphyrio* L.) having diverged from a common ancestor approximately two million years ago (Olson, 1973; Sibley and Ahlquist, 1990). The two species share many morphological and behavioural characteristics although pukeko are smaller, have relatively longer appendages, are capable of flight, and tend to live in communal groups (Jamieson, 1994). Since their invasion of New Zealand from Australia within the past 800 years (Millener, 1981), pukeko have flourished in lowland swamps and moist pastures. Unlike takahe, they have been able to expand their distribution and numbers since European colonisation and the subsequent clearing of extensive areas of forests for agriculture. The pukeko's success is due not only to their ability to fly and better predator awareness and defence behaviour (Bunin and Jamieson, *in press*), but may also relate to their high reproductive rate. Pukeko usually lay five eggs compared to the takahe's two and can produce multiple broods within a season, while takahe only renest if the first clutch fails and generally only raise a maximum of one chick per year.

Although their natural ranges do not overlap today, takahe and pukeko do co-exist on Mana, Tiritiri Matangi, and Kapiti Islands, following recent transfers of adult takahe to these offshore refuges. We describe the results of a pilot study designed to examine the feasibility of cross-fostering takahe eggs to pukeko nests on Mana Island. This manipulation was intended to increase the number of juveniles produced per pair, as takahe will renest if initial clutches are lost or removed. A similar cross-fostering experiment has saved the Chatham Island black robin (*Petroica traversi* Buller) from certain extinction (Butler and Merton, 1992).

We also predicted that cross-fostered takahe would learn some adaptive behaviours such as predator awareness from their pukeko foster parents; if this is the case, the cross-fostering technique could ultimately be used to improve the effectiveness of predator defence behaviours, and thus increase survivorship of takahe released on mainland New Zealand where introduced predators are common. Details of experiments designed to compare the predator response behaviours of the two species (including cross-fostered and parent-reared takahe) have been reported elsewhere (Bunin and Jamieson, *in press*).

# Methods

### Study area

Mana Island is 217 ha in area and lies approximately 21 km north of Wellington and 4 km off the North Island's western coast. Three pairs of takahe were transferred to Mana Island in 1987. At the beginning of this study in September 1993, there were five breeding pairs and a trio on the island. While pukeko were only rarely seen on Mana Island a decade ago (P. Todd, *pers. comm.*), the self-introduced population has grown to approximately 300 birds. As in other populations in New Zealand, pukeko on Mana Island breed in family groups ranging in size from two to twelve birds, often including several non-breeding helpers (Craig and Jamieson, 1990; Jamieson, 1994). Bunin (1995) reports details of interactions between the resident populations of takahe and pukeko on Mana Island.

### Cross-fostering procedure

After a takahe nest was located, the eggs were candled at 10 - 15 days of age and then every 5 - 10 days thereafter until hatching, at approximately 30 days. Approximation of the stage of development of the embryo is based primarily on the size and orientation of the air-cell at the blunt end of the egg (Eason, 1992). Infertile eggs or ones with dead embryos were removed to promote re-nesting.

In the 1993 - 94 season takahe eggs were transferred into pukeko nests after the chick entered the air-cell (approximately 24 - 48 h prior to hatching). This occurs at 28 - 29 days into incubation and is the stage at which the chick becomes vocal. At the outset of the 1994 - 95 breeding season we determined, using a temperature probe, that both takahe and pukeko incubation temperatures range from 36 - $40^0$ C. Therefore, in the 1994 - 95 season, takahe eggs were transferred into pukeko nests as early as 10 days prior to hatching, which allowed for greater flexibility in choosing foster nests.

In all egg transfers, transport incubators were used to keep the eggs warm and protected from damage. Two types of incubators were employed over the course of this research: a cylindrical canister which used hot water as the heat source, and a larger wooden box which had a thermostatically controlled, battery powered motor providing heat. Takahe eggs from Mana, Maud and Kapiti Islands were used for cross-fostering. A helicopter was used for five inter-island transfers, and a motorboat and a float plane were each used on a single occasion.

Prior to transferring takahe eggs into the nests of pukeko, the pukeko's eggs were removed and replaced with dummy eggs. Initially, we used pukeko eggs that had been blown and filled with wax (Fig. 1a). However, the shells became brittle and could not be re-used in many cases, so we switched to dummy eggs which had been made from plaster of Paris and painted by hand (Fig. 1b). Pukeko nests in high quality habitat (abundant

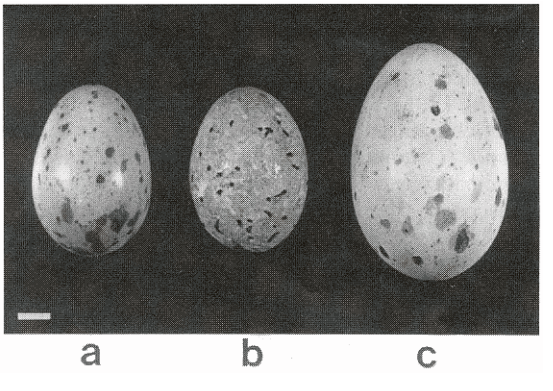


Figure 1: *Dummy eggs used in the cross-fostering experiment. (a) Blown and wax-filled pukeko egg. (b) Plaster of Paris hand-painted pukeko egg. (c) Blown and wax-filled takahe egg. (Scale bar = 1 cm)*

herbaceous vegetation, water, and cover) which could be observed and monitored relatively easily were selected. Once pukeko were incubating a clutch of dummy eggs, and a takahe egg became available for cross-fostering, one of these dummy eggs was replaced with a wax-filled takahe egg (Fig. 1c), which is approximately two and a half times larger than a pukeko egg.

The final step in the transfer was the replacement of the dummy takahe egg with a live takahe egg. Unlike takahe, pukeko always left the nest as it was approached. After swapping eggs, we watched the nest from a nearby hide to be certain that the pukeko returned. "Back-up" nests were always available in the event that the pukeko did not return to the nest quickly enough. If the incubating pukeko did not return to its nest within 15 - 30 min (depending on the weather) the egg was removed, warmed, and transferred to the back-up nest.

The progress of cross-fostered chicks was monitored daily from a hide for the first two weeks after hatching, and then at least three times a week until the chicks were seven weeks old. Monitoring was reduced to approximately once a week after this age. For comparison, takahe chicks from parent-reared nests on Mana and Maud Islands were checked with similar frequency by Department of Conservation staff; chicks on Kapiti Island were checked less regularly, 1 - 2 times a week. All dead eggs and chicks (assuming carcasses could be found) were sent to the Department of Veterinary Pathology, Massey University, Palmerston North, for *post mortem* analyses although only a portion of these have been examined to date.

# Results

Pukeko never abandoned a clutch of dummy eggs once they had begun incubating, and one group incubated a clutch of dummy eggs for over eight weeks (almost five weeks longer than normal) before the eggs were removed. However, because the results of the 12 cross-fostering trials varied substantially, we first present details of the outcome of each trial, followed by an overall summary of the results.

In the 1993 - 94 breeding season, four takahe eggs were cross-fostered to pukeko. The first of the transferred eggs arrived from Maud Island on 9 October 1993. The chick hatched on 12 October, and pukeko foster parents were observed feeding it on 14 and 15 October. In this case alone, one pukeko chick was allowed to hatch along with the cross-fostered takahe chick. As a result, although chick-feeding behaviour by the foster parents was observed for over two weeks thereafter, it was impossible to be sure whether one or both of the chicks were alive at that point. The cross-foster chick was not observed over the following two months and no carcass was found.

The second egg, taken from a pair of takahe on Mana Island, was transferred to a pukeko nest on 22 November, but failed to hatch. The chick reached the pipping stage but did not rotate within the shell. There were some complications associated with the transfer, as the initial pukeko foster parents did not return to the nest within the 30-min period after exchange. After warming the egg, it was placed in a second pukeko nest, but they too did not return quickly enough. The egg was then returned to a takahe nest to be incubated for several hours. The transfer procedure was then repeated and the pukeko foster parents returned to the nest within 10 min. It is possible that these complications caused the chick to cool as it was about to hatch, although it was still quite vocal when it was placed in the nest of the foster parents the final time. It is unusual for a takahe chick not to hatch once it has reached the pipping stage, even with some cooling, unless there are other complications such as a bacterial infection (D. Crouchley, *pers. comm.*). Results of *post mortem* analysis were inconclusive.

The third egg was taken from Maud Island on 29 November. The chick hatched on 1 December and remained in its natal territory, where it was fed and cared for by its foster parents for seven weeks. At this stage it was apparently killed and eaten, most likely by an Australasian harrier (*Circus approximans* Peale) which were regularly seen over the territory prior to the chick's death. However, it is possible that the chick may have died from some other cause and been scavenged afterwards.

The fourth egg came from Kapiti Island on 27 December and was temporarily placed under an incubating pair of takahe on Mana Island, as it was considered too young for immediate transfer to a pukeko nest. The egg was transferred to a pukeko nest on 6 January and hatched on 8 January. As a chick, it was fed by all four pukeko adults in the group, as well as by two juveniles produced in the first clutch of the season. The cross-fostered juvenile remained in its natal territory with its foster parents until the beginning of the 1994 - 95 breeding season. On 1 October 1994, it was caught, sexed as a female, and placed in a large enclosure (25 m x 40 m) with a male juvenile takahe from Maud Island that had been parent-reared. These birds were too young to produce offspring, but quickly formed a pair-bond. They were seen in close association only one day after being placed together, and were observed together from that point onwards, even after release

from the enclosure in January 1995. No unusual behaviours suggesting mal-imprinting have been observed in the cross-fostered takahe, although it did appear more wary than conspecifics when exposed to a model predator (Bunin and Jamieson, *in press*).

In the 1994 - 95 breeding season, eight more takahe eggs were cross-fostered to pukeko. The first of these was taken from a pair of takahe on Mana Island on 24 September 1994. It hatched the following day and was still associating with its foster group as of May 1995. This was the only cross-fostered chick to have survived from the 1994 - 95 breeding season.

The second egg was transferred from Kapiti Island on 28 September. It reached the pipping stage by 1 October, but was never seen again. We surmise that the chick failed to hatch and was removed from the nest by an adult.

The next egg arrived from Maud Island on 1 October and hatched under pukeko on 5 October. This chick was regularly observed for two weeks but was not seen after this and no carcass was found despite extensive searches.

The fourth egg was taken from Mana Island on 3 October, transferred to a pukeko nest, and hatched on 11 October. It was observed regularly for two weeks and then its carcass was found 10 days later. From the state of the carcass, death was estimated to have occurred on 1 November, three weeks after hatching. *Post mortem* analysis revealed that the chick had pneumonia as well as several lesions on the chest and leg. It was concluded that the weakened chick may have been attacked by a neighbouring group of pukeko (S. Haigh, *pers. comm.*).

The fifth egg was also taken from Mana Island. It was transferred to a pukeko nest on 14 November and hatched the following day. It was not observed after one week and no carcass was found despite extensive searches.

The sixth egg arrived from Kapiti Island on 16 November and hatched on 18 November. It was seen regularly until 7 January (seven weeks later). Once again, extensive searches for the remains were unsuccessful.

The next two eggs came from Mana and Maud Islands and were transferred into pukeko nests on 16 November and 12 December, respectively. Both eggs failed to hatch under their pukeko foster parents. The *post mortem* analysis of one of these eggs revealed that the embryo may have been malpositioned within the egg, and the presence of gram negative bacteria indicates that it was infected near the time of oviposition (S. Haigh, *pers. comm.*). These micro-organisms may have been responsible for the death of the embryo.

Overall, 67% (8/12) of cross-fostered eggs hatched successfully, with 25% (2/8) of these still alive at one year of age (Table 1). Hatching and fledging success of takahe eggs from the same clutches as the eggs taken for cross-fostering (above) were 42% (5/12) and 40% (2/5), respectively (Table 2). There is no significant difference in hatching or fledging success when comparing cross-fostered to parent-reared eggs (Fisher's exact test, $P = 0.41$ and $P = 0.62$, respectively). This comparison between cross-fostered and parent-reared eggs eliminates confounding influences of variations in reproductive success among pairs or in a given pair over time. However, when comparing hatching success, it must be remembered that only eggs which were fertile and apparently developing normally at the time of transfer were used for cross-fostering. If infertile eggs (n = 6) are excluded, the hatching success of parent-reared takahe eggs in the same clutches as eggs taken for cross-fostering increases to 83% (5/6) (Table 2), but is still not significantly different from hatching success of cross-fostered eggs (Fisher's exact test, $P = 1.0$).

Pairs that had eggs removed for cross-fostering and that failed to hatch an egg of their own, subsequently re-nested and layed a replacement clutch. The one exception to this was a case where the transfer had taken place at the end of the breeding season. This cross-fostered chick did survive, however, so the productivity of this pair of takahe was not reduced as a result of the manipulation.

Over the course of this research, takahe on Mana Island laid a total of 28 eggs, five of which were transferred to pukeko. Of the eggs left with their parents, only 22% (5/23) hatched successfully and 60% (3/5) of these were still alive as of May 1995. The two chicks which did not survive died at six and eight days old. Of the remaining eggs, 72% (13/18) were either infertile or died at very early stages of embryonic development, 22% (4/18) died just prior to hatching (full-term dead embryos), and 6% (1/18) died midway through incubation. *Post mortem* results have only been obtained for the chick which died at six days of age; these indicate that the chick had a deformed neck at the time of death.

Over the two field seasons on Mana Island, no unusual or aggressive behaviours from the pukeko foster parents towards their chicks or foster chicks were observed. Takahe parents appear to have a closer physical association with their chicks than pukeko parents had with theirs, at least in the presence of humans. When their territory was approached by humans, at least one takahe parent would always remain with their chick, while pukeko parents would generally flee, leaving their chick(s)

Table 1: *Fate of all cross-fostered takahe eggs on Mana Island.*

| Island of origin | Transfer date | Hatch date | Cause of death | Chick age at death (days) |
|---|---|---|---|---|
| Maud | 9/10/93 | 12/10/93 | unknown | 4 |
| Mana | 22/11/93 | failed | chilling? | - |
| Maud | 29/11/93 | 1/12/93 | predation? | 48 |
| Kapiti | 27/12/93 | 8/1/94 | alive | alive |
| Mana | 24/9/94 | 25/9/94 | alive | alive |
| Kapiti | 28/9/94 | failed | unknown | - |
| Maud | 1/10/94 | 5/10/94 | unknown | 15 |
| Mana | 3/10/94 | 11/10/94 | pneumonia? | 21 |
| Mana | 14/11/94 | 15/11/94 | unknown | 7 |
| Kapiti | 16/11/94 | 18/11/94 | unknown | 50 |
| Mana | 16/11/94 | failed | bacterial infection? | - |
| Maud | 12/12/94 | failed | unknown | - |

Table 2: *Fate of eggs that were parent-reared by takahe following the removal of one egg from the clutch for cross-fostering (as shown in Table 1).*

| Island | Initial clutch size | Hatch date | Cause of death | Chick age at death (days) |
|---|---|---|---|---|
| Maud | 2 | failed | infertile | - |
| Mana | 2 | failed | infertile | - |
| Maud | 3 | failed | infertile | - |
| | | 27/11/93 | thin heart? | 8 |
| Kapiti | 2 | failed | mid-embryo death | - |
| Mana | 2 | 23/9/94 | neck deformity | 6 |
| Kapiti | 1 | (transferred) | - | - |
| Maud | 2 | failed | infertile | - |
| Mana | 2 | failed | infertile | - |
| Mana | 2 | 18/11/94 | alive | alive |
| Kapiti | 2 | 15/11/94 | alive | alive |
| Mana | 3 | failed | infertile | - |
| | | 24/11/94 | unknown | 8 |
| Maud | 1 | (transferred) | - | - |

alone. On several occasions when cross-fostered chicks were left alone in this manner, they emitted a loud distress call. Such a call was never heard from any of the parent-reared takahe chicks. Pukeko chicks left alone by their parents would generally hide and remain quiet until their parents returned. It should be noted that the presentation of model predators to pukeko never caused them to flee from their territory nor did it result in their cross-fostered takahe chicks emitting distress calls (Bunin and Jamieson, *in press*).

Reverse cross-fostering was also carried out with one pair of takahe which continued to incubate an empty nest more than two weeks after having their single inviable egg removed. This behaviour stopped once their cross-fostered pukeko chick hatched. They subsequently raised this chick to independence, before being transferred to another island. The cross-fostered pukeko juvenile was last seen with a group of pukeko that held a territory which overlapped with the cross-fostered birds' natal territory.

# Discussion

Cross-fostering takahe eggs to pukeko was a complicated, delicate, and time-consuming procedure, particularly when it involved moving eggs between islands. On first inspection of the cross-fostering results, one might be tempted to label it a failure as only two cross-fostered chicks survive from the total of 12 eggs. However, it must be remembered that takahe have relatively low productivity in their natural alpine habitat, with a modal clutch size of two, egg infertility ranging

from 20% to 30%, hatching success from 40% to 70%, and survival of chicks to one year ranging from 27% to 71% (Reid, 1967; Eason, 1992; Clout and Craig, 1995). Furthermore, over the two years of our research on Mana Island, takahe had an even lower hatching success of only 22% with only three juveniles surviving as of May 1995, from a total of 23 eggs (excluding eggs transferred to pukeko nests). While the takahe's mainland habitat is considered "sub-optimal" (Clout and Craig, 1995), survival up to three months of age in island populations is lower than what has been reported for takahe living in Fiordland (Bunin *et al., in press*). Conducting a cross-fostering experiment in this environment, with a population of takahe apparently suffering from low hatchability, may not be a fair test of the feasibility of this technique as a management tool. Further research on possible causes of low hatching success on islands should be conducted before proceeding with the cross-fostering program.

Despite small sample sizes and limited success in terms of survival, we have demonstrated that pukeko adults will accept and successfully incubate the much larger takahe egg, and care for takahe chicks as their own. Furthermore, pukeko adults react more vigorously to model predators (stoats *Mustela erminea* L.) than adult takahe, and in one case where they were tested, a cross-fostered yearling takahe exhibited higher levels of alertness and avoidance behaviour than a parent-reared yearling takahe (Bunin and Jamieson, *in press*). These preliminary findings indicate that cross-fostering to pukeko could play an important role in the future management of takahe in New Zealand, especially if takahe are to be released at mainland sites where terrestrial mammalian predators are present. At the very least, these results should encourage further cross-fostering research involving takahe as well as other endangered avian species.

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