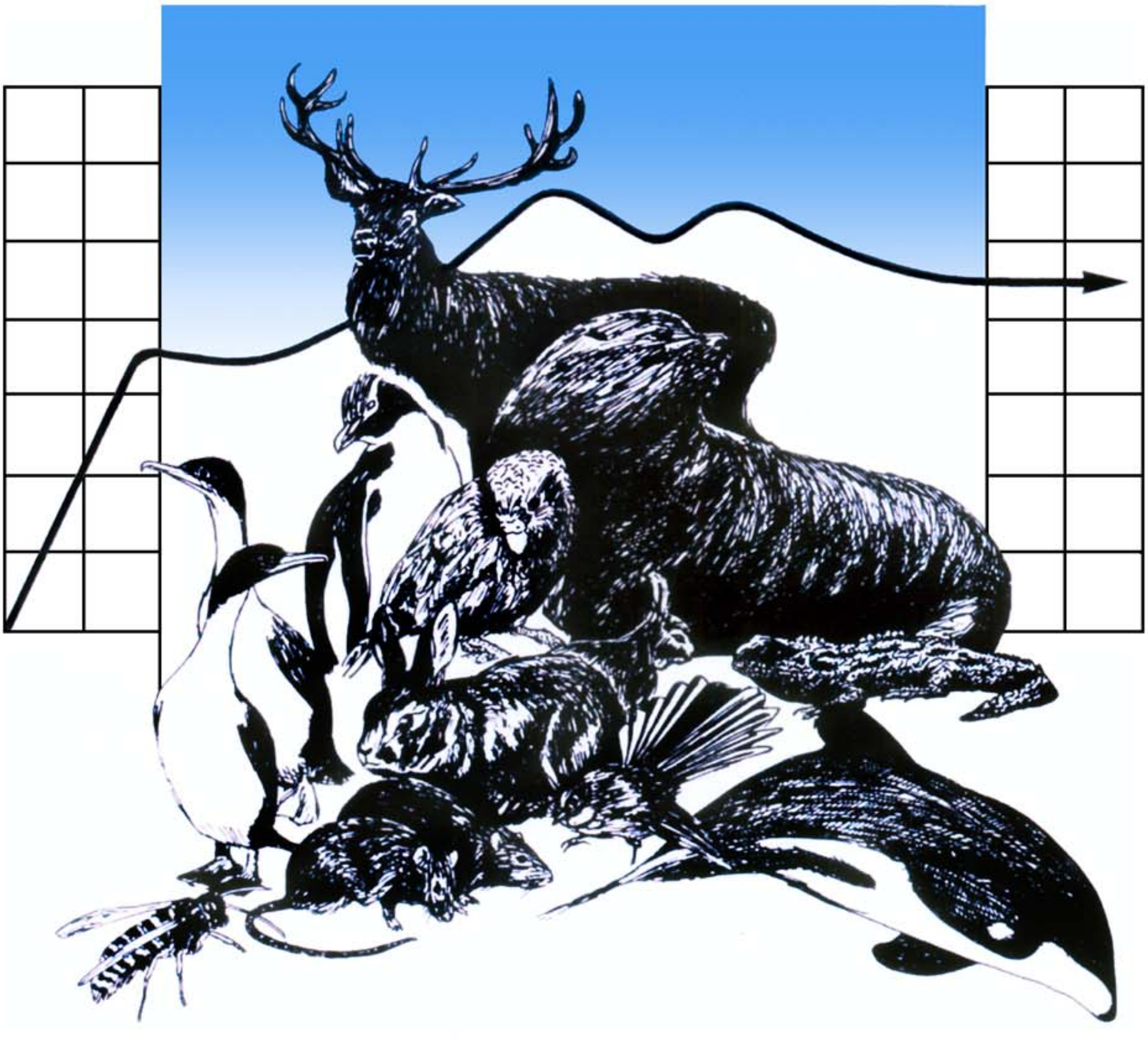
DEPARTMENT OF ZOOLOGY



WILDLIFE MANAGEMENT

The effect of temperature on the hatching success of the endangered takahe (*Porphyrio hochstetteri*)

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Abstract

The endangered takahe (*Porphyrio hochstetteri*), endemic to New Zealand, has been heavily managed in an attempt in increase their low numbers, and control the factors leading to their decline; particularly their vulnerability to predation by introduced mammals. To increase recruitment into wild populations, artificial incubation practices were developed at the Burwood Bush Rearing Unit to maximise the number of chicks produced each season. Initially, the average temperature that takahe eggs were exposed to was 37.4°C, however, later trials with wax-filled eggs indicated that natural incubation temperatures were much lower. Based on this, and the poor hatching success of freshly laid eggs placed in artificial incubation, a series of temperature trials were carried out. The results of this study show that all of the eggs kept at an average temperature below 36.9°C hatched successfully with no assistance to hatch, whereas those kept above 36.9°C were less likely to hatch and required assistance. These temperature trials show that an optimum temperature is likely to lie between 36.1 and 36.8°C, most likely close to 36.5°C. However, further temperature trials are required to confirm this.

Keywords: Takahe, *Porphyrio hochstetteri*, artificial incubation, temperature, hatching success

Introduction

Although conservation efforts have been carried out for over a century, it has only been in the past century that it has become widespread (Edwards & Abivardi, 1998). The massive increase in extinctions and extirpations throughout the world has highlighted the need for more developed conservation methods, such as captive breeding and rearing, which have the potential to increase survival, and thus population growth, by protecting the animal during its high-risk life stages (Maxwell & Jamieson, 1997).

One species that has benefited from intensive captive management is the takahe (*Porphyrio hochstetteri*) (Eason and Willans, 2001). The flightless bird endemic to New Zealand was thought to be extinct until 1948, when it was rediscovered in the Murchison Mountains in Fiordland (Bunin & Jamieson, 1996; Lettink et al. 2002). Since then, the species has been heavily managed due to their low numbers, limited habitat and vulnerability to predation by introduced mammals, particularly the stoat (*Mustela erminea),* and much research has been put into conserving the species, ranging from predator and competitor control to translocations and captive-breeding (Crouchley, 1994; Bunin & Jamieson, 1996; Maxwell & Jamieson, 1997).

Despite such intensive management, the takahe population has continued to decline over time (Bunin & Jamieson, 1995). To help boost the recruitment rate, artificial incubation practices were developed to maximise the number of chicks produced each season. Artificial incubation has been used in a number of species, ranging from the domestic hen (*Gallus gallus*) to the Californian condor (*Gymnogyps californianus*), in order to maximise hatchability and increase recruitment into the population (Kuehler & Witman, 1988; Deeming, 2002).

The Burwood Rearing Unit was established in 1985 to provide two primary functions: (1) Captive rearing of wild eggs and chicks for release and; (2) Captive breeding to produce an alternative source of eggs and chicks (Eason and Williams, 2001). Several eggs are taken each season from captive pairs at the Burwood Bush Rearing Unit, as well as from wild pairs in the Murchison Mountains, for artificial incubation and rearing at Burwood Bush Rearing Unit (Crouchley, 1994; Maxwell & Jamieson, 1997). Pulling eggs from nests mimics the loss of a clutch through predation, thus encouraging the pairs to produce another clutch (Deeming, 2002), thereby potentially increasing the number of fertile eggs and chicks produced per season.

A core temperature of 37.4^{o}C was suggested to be best for artificial incubation, as this worked for other avian species with similarly sized eggs (R. Curtis, pers comm.) and the accepted average incubation temperature for most eggs is 37.5^{o}C (Deeming, 2002). However, recent trials using wax-filled 'dummy' eggs that contain a temperature probe have shown that the temperature of a nest during natural incubation ranges from 34.6 to 36.3^{o}C, with an average of 35.5^{o}C (Curtis, R., 2008, unpublished data). Two similar trials in 2005 showed that the average temperatures in two natural takahe nests were 33.4 and 34^{o}C respectively (Curtis, R., 2005, unpublished data). A study carried out to compare temperatures and hatching success in wild nests found that in nests where the chick hatched, the median temperature was 35.6^{o}C with a maximum temperature of 37.4^{o}C (Maxwell & Christie, 2005). However, these samples were too small (n=4) to determine the statistical significance of different temperatures.

Previous studies in several avian species have shown that too high a temperature can lead to a number of problems, including rapid development of embryo, early internal pip, physical abnormalities, a decrease in the absorption of the yolk sac during hatching, and resulting in weaker chick that is less capable of hatching (French, 2000; Eason & Willans, 2001; Curtis, 2007). Refining the optimum temperature for takahe eggs under artificial incubation increases the potential for increasing hatching success and therefore increasing the recruitment rate of juveniles into both captive and wild populations. The aim of this study is to determine whether the recent temperature trials, where artificial incubation temperatures were dropped from 37.4 to 36.1°C were effective in increasing hatching success. It is believed that 37.4°C is too warm for the embryo to develop correctly, and that decreasing the average temperature during incubation will aid in increasing hatchability. Relative humidity during incubation will also be looked at, as this has been identified as a major cause of embryo death in a number of species (Philby et al. 1991; Eason & Willans, 2001; Deeming, 2002).

Methods

Data from the past five seasons at the Burwood Rearing Unit (2002/2003 season to 2008/2009 season) was analysed to determine the minimum, maximum and mean temperatures and relative humidity that the artificially incubated eggs were exposed to. Eggs that were brought in for artifical incubation after they were one day old were removed from the analysis as the temperature of the natural nest was unknown. Infertile eggs were also removed from the analysis to remove bias towards unsuccessful hatches. Only data from artificial incubation was used due to the lack of data on temperature and hatching success in natural nests, which would be very difficult to obtain, and risks the parents abandoning the nest if disturbed too often.

During the incubation trials, latex gloves were worn whenever eggs had to be handled. The eggs were weighed every second day, and candled every fourth day to determine development. This continued until day 23, when eggs were then weighed and candled every day. A model was used, in which the egg's weight was recorded, to determine the appropriate humidity for each egg to lose 18% of its weight from lay to internal pip. All of the incubators were forced-air incubators, kept at 40%, 45% and 50% relative humidity with two other incubators available for eggs that required humidity conditions different to those. The average temperature for the first 2 seasons was 37.4°C, and then decreased to 36.5°C by the 5th season.

The eggs were classified as 'Success' or 'Failure' where hatching success was determined by observing the external pip. This is the stage where the chick first breaks the shell and is the beginning of hatching. The external pip was used as the determinant of hatching success in order to control for factors such as assisted hatching or situations where the chick was unable to completely hatch, such as due to the shell being too thick or dry.

A one-way ANOVA was used to determine the effect of temperature on hatching success and the relative and attributable risk were calculated for the two categories, divided by temperatures < 37°C and ≥ 37°C and based on hatching success.

Results

Table 1 compares the minimum, average and maximum temperatures between the successes and failures, as defined by whether or not they reached external pip. The successful category showed a difference of 1.31°C between the mean maximum and minimum temperatures, whereas the failed group had a difference of 0.47°C. The average temperature differs slightly, where the average temperature of the successful group is 0.53°C lower than that of the 'failure' group.

Table 2 shows the outcome of the chicks which externally pipped, including their hatch type (i.e. assisted by Burwood staff or a natural hatch). Whether or not the chicks survived beyond a week is also given. Three weeks was used as the cutoff date as this is when chicks that are affected by conditions such as yolk sac infection or physical defects, are most likely to die. The results show that six out of the seven chicks kept at an average temperature of 36.9 and above had to be assisted to hatch, and died young due to conditions such as yolk-sac infection and intestinal problems. In comparison, all of the chicks incubated at an average temperature between 36.1 and 36.8 hatched naturally, and only one out of the four died.

The results of the ANOVA show that temperature does play a role in hatching success ($p= 0.002$), where eggs kept at an average temperature equal to or greater than 37°C are 77% more likely to fail to external pip than those kept under 37°C (relative risk= 0.77, attributable risk= 0.77; see Table 3). Humidity does not appear to be as important ($p= 0.595$) as temperature under these circumstances.

Table 1: Comparison of artificial incubation temperatures between successful and unsuccessful hatches.

	Success		Failure	
	Mean	Range	Mean	Range
Minimum (°C)	35.83	34.8-36.5	37.2	36.8-37.4
Maximum (°C)	37.14	36.6-38.6	37.67	37-38.7
Average Temperature (°C)	36.75	36.1-37.3	37.28	37-37.4

Table 2: Table showing the fate of the chicks that were kept in artificial incubation throught the entire developmental period, that reached the stage of external pip. This includes whether or not the hatches were assisted, and their fate (death or survival) within three weeks of hatching.

Year	Name	Ave temp.	Hatch type	Fate	Cause
2005-2006	TFz2	37.3	Assisted	Survived	
2006-2007	AOo1	37	Assisted	Died within 24 hours	Intestinal problems
	TFx1	36.8	Natural	Survived	
2007-2008	AOo2	37	Assisted	Died at 11 days	Unknown
	AOx2	36.9	Assisted	Died at 4 days	Yolk-sac infection/ Intestinal problems
	MGz2	36.9	Assisted	Died within hours	Ruptured yolk-sac
	TFo2	36.9	Assisted	Euthanised at 20 days	Splayed legs, unable to walk properly
	TFz2	36.9	Assisted	Died within 4 days	Yolk-sac infection
2008-2009	AOo1	36.1	Natural	Survived	
	WCo1	36.3	Natural	Died at 4 days	Intestinal problems
	WCx1	36.2	Natural	Survived	

Table 3: Table showing the success and failure rate of artificially incubated eggs, categorised by average temperature (‘greater than or equal to 37°C’ or ‘less than 37°C’) as determined by external pip.

Average temperature	Success	Failure	Total
< 37°C	8	0	8
≥ 37°C	3	10	13
Total	11	10	21

Discussion

The aim of this study was to investigate the effect of temperature on hatching success, as it was believed that 37.4°C is too warm a temperature for the embryo to develop correctly, due to the poor hatching success in early incubation trials. Previous studies support this view, claiming that the survival of eggs depends on their rates of heating and cooling, and that extreme temperatures, particularly during early incubation, may induce developmental defects that may compromise the chick later in development and lead to physical abnormalities and weaker chicks (French, 2000; Eason & Willans, 2001; Maxwell & Christie, 2005; Curtis, 2007; D. Eason, pers. comm.). This could explain why in the early trials where the temperature was kept at 37.4°C, late death embryos died at day 23-25, approximately one week before hatching. This would also explain why hatching success was much poorer in the early temperature trials, and why takahe eggs became notorious for being difficult to hatch when removed from nests before they are two weeks old (Curtis, 2007; M. Smart, pers. comm.).

The results of this study suggest that 36.8°C is the cut-off temperature, above which the embryos showed rapid development and an early internal pip, as well as producing weaker chicks that required assistance to hatch (Curtis, 2008). Six out of the seven chicks kept at an average temperature of 36.9°C and above had to be assisted to hatch, and died young due to conditions such as yolk-sac infection and intestinal problems (see Table 2). In comparison, all of the chicks incubated at an average temperature between 36.1 and 36.8 °C hatched naturally, and only one out of the four died.

By fine-tuning the incubation procedures used at Burwood Bush, it makes it possible to remove eggs from nests at any age, and not only increases the likelihood of a successful hatch, but decreases the risk of temperature-induced developmental problems. This in turn increases the number of chicks able to be reared and recruited into the population, thus increasing the population of this endangered bird.

Recommendations

On the basis of the results of this study, I would recommend that the average temperature of 36.5°C be used to incubate further takahe eggs. I would also recommend that the temperature trials are continued, where temperatures between 36 and 36.8°C are tested to find an optimum incubation temperature. The successful, natural hatching of eggs kept between 36.1 and 36.8°C indicates that an optimum may lie there, but a larger sample size is required to make definite claims.

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