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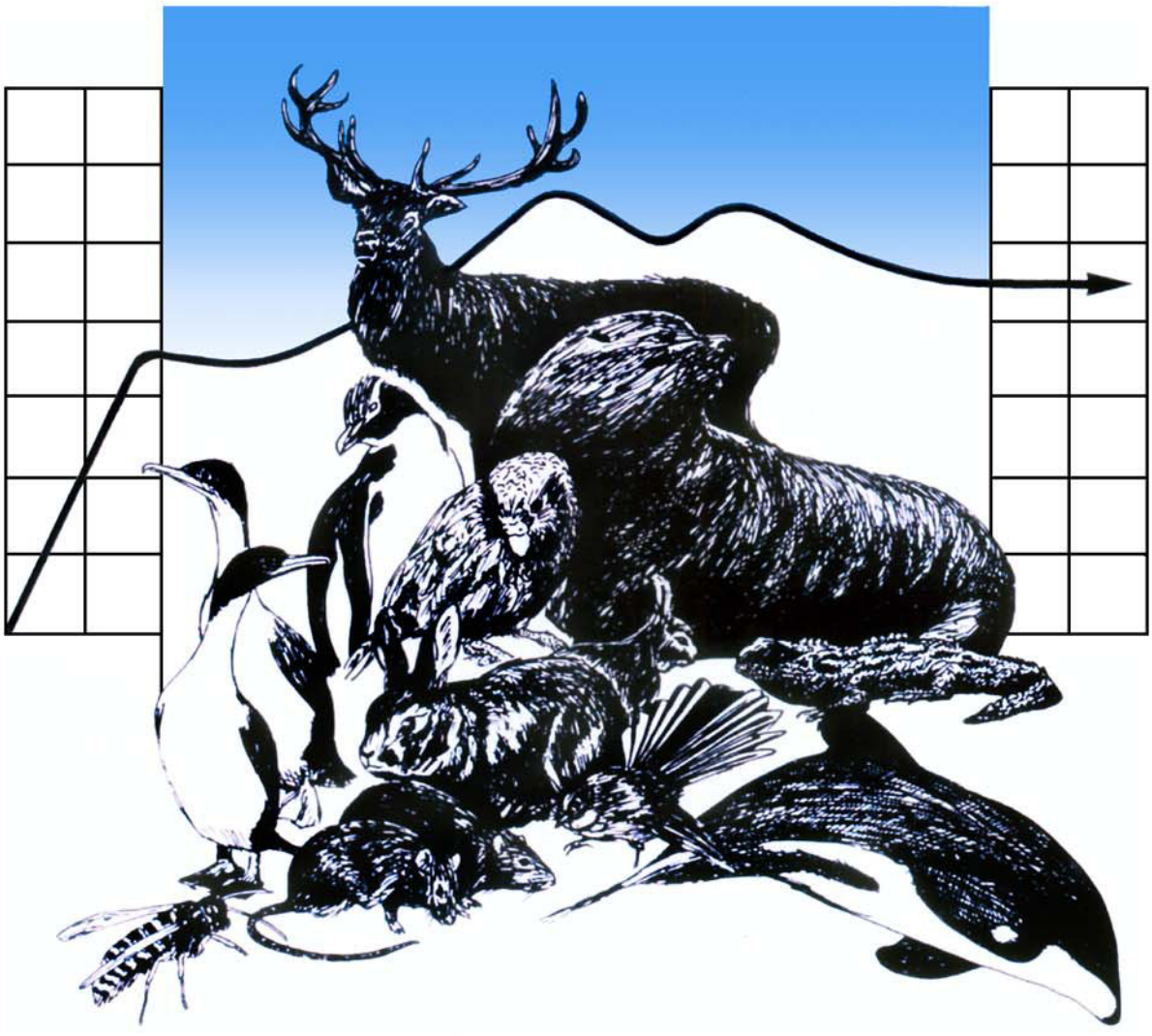

WILDLIFE MANAGEMENT

Collation and Analysis of current data on the great spotted kiwi (Apteryx haastii)

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A report submitted in partial fulfilment of the
Post-graduate Diploma in Wildlife Management

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Abstract

Great spotted kiwi (GSK) populations are in decline. Recent concern about the abundance and range of GSK has led to more intensive management and research on them. Management includes the Bank of New Zealand Operation Nest Egg (BNZONE) where eggs are removed from the wild and hatched in captivity. This report collated and analysed current data related to reproductive rate and breeding behaviour of GSK. The percentage of GSK incubated to full term in the wild was 29% compared to 79% for eggs incubated in captivity. This value was similar to previous research however there is limited knowledge about the effect of predator control on this value. There was no evidence to suggest a difference in the proportion of eggs incubated to full term at different times of the breeding season. 57% of eggs that were unsuccessful were replaced with a second egg and 23% of the second laid eggs were incubated to full term. The average number of days between an incubating adult's first egg being taken and the beginning of a second incubation attempt was 60 ± 11days. It is possible that it takes 60 days for female GSK to gain enough energy to replace the lost egg. Male GSK spent on average 1 – 1.5 hours longer incubating an egg each night than females. Further study on the effect of predator control would help determine the best egg removal strategy. Many of the results were based on low sample sizes and understanding of GSK breeding behaviour will be likely to increase over time as more information is collected.

Key words: Great spotted kiwi reproductive rate, incubation, vhf transmitter.

Introduction

There are currently five species of kiwi (Apteryx); the little spotted kiwi (Apteryx owenii), great spotted kiwi (A. haastii), brown kiwi (A. mantelli), rowi (A. rowi) and tokoeka (A. australis) (Holzapfel et al. 2008). Since human arrival all species of kiwi have declined substantially and are currently threatened on the mainland (McLennan et al. 1996; Basse et al. 1999). The great spotted kiwi (GSK) is the most elusive of the kiwi species, and as such has received little research and monitoring.

There are three main populations of GSK, in the northwest Nelson area, Paparoa Range and the Arthurs Pass/ Hurunui district (McLennan & McCann 1994). There have been few estimates of the abundance of GSK and the rate of their decline. Robertson (2003) estimated a total of 85,000 GSK in 1996 which would decline to 57,000 by 2006, yet Holzapfel et al. (2008) estimated only 16,000 GSK in 2008 which is likely to decline to 13,000 by 2018. In 2008, GSK were classified as nationally vulnerable under the New Zealand Threat Classification System (Miskelly et al. 2008).

The main reasons for the decline in GSK include habitat loss and predation on eggs and chicks by introduced mammals such as stoats (Mustela erminea), dogs (Canis lupis familiaris; McLennan & McCann 1994; McLennan et al. 1996) and cats (Felis catus; Robertson 2004).

GSK are flightless and largely nocturnal (Holzapfel et al. 2008). They feed on a varied diet of invertebrates and fruit, and use hollow logs or dense vegetation for day time burrows and nests (Holzapfel et al. 2008). The weight of adult GSK can range between 1750g – 4300g (McLennan & McCann 1994) with females being the heavier sex. McLennan & McCann (1991) in Keye (2008) observed the breeding season to range from July till early November, however some GSK have laid eggs as late as January (M. Wiley, pers. comm.). Unlike some other kiwi species, both the male and the female will incubate an egg, with the male incubating during the day and the female incubating at night (Marchant & Higgins 1990). The daily activity of adult GSK drops suddenly when a single egg is laid and incubation begins (M. Wiley, pers. comm.). The egg is incubated for approximately 78 days before hatching (Holzapfel et al. 2008, S. Horan, pers. comm.). It is thought that male kiwi spend more time incubating than

females; however there is little knowledge of how the pattern of incubation changes throughout the incubation period (J. Welsh, pers. comm.).

Recent concern about the abundance and range of GSK has led to more intensive management and research on GSK. Since 2007 management of GSK has included the Bank of New Zealand Operation Nest Egg (BNZONE) where eggs are removed from the wild into captivity to try and increase their survival through vulnerable life stages (Kiwi Recovery 2011). Currently the BNZONE has allowed collection of 68 GSK eggs from the wild, of which 54 have hatched and 25 are currently still alive (M. Wiley, pers. comm.). The hatch rate and chick survival through the BNZONE is thought to be much higher than in the wild. However the hatch rate and chick survival is still largely unknown in the wild, especially in areas where predator control has been used. The only known estimate of egg hatch rate in the wild is from McLennan et al. (1996) who found that 37% of GSK eggs that were laid hatched, however this value was calculated from only 19 eggs. Since kiwi eggs and chicks below 1000g are thought to be a lot more vulnerable to predation than adults (McLennan et al. 2004), the BNZONE is expected to increase egg and chick survival of GSK by removing the predation risk.

Through the BNZONE, around 24 eggs are removed from the wild each year (M. Wiley, pers. comm.). However, as with any egg removal from a population, there are potential impacts on the source population. These impacts may be large in some areas such as the lower Hawdon Valley where almost all GSK eggs are taken into captivity (J. Welsh, pers comm.). The resulting juveniles in captivity are currently being introduced to the Nina valley, in Lewis Pass, to extend the range of GSK, rather than restocking the Hawdon Valley where the eggs originated from (M. Wiley, pers. comm.).

It has been identified in literature that GSK have the potential to lay a second egg if their first egg is unsuccessful (Holzapfel et al. 2008; McLennan & McCann 1991 in Keye 2008). Although kiwi eggs are large in size, it is possible that they are not too energetically expensive for the female to be able to produce two eggs in one season (McLennan et al. 2004). Calder et al. (1977) found that the energy contained within a brown kiwi (A. mantelli) egg was on average 4014KJ of which half is thought to come from stored reserves accumulated over time (McLennan 1988). Furthermore some species of kiwi such as the brown kiwi (A. mantelli) often incubate more than one egg at

one time (Robertson 2003). If GSK do lay a second egg after their first egg is taken, this could increase the effectiveness of the BNZONE and reduce the impact on source populations. However, the proportion of kiwi that will lay a second egg is currently unknown. Furthermore second laid eggs may not have the same hatch rate as the first. A study on black headed gull eggs (Chroicocephalus ridibundus), from sites where clutches of eggs were harvested, found that eggs were smaller with less yolk and a thinner shell than eggs from non harvested sites. This was because of the reduction in female endogenous food reserves, resulting in lower hatching success and chick survival (Wood et al. 2009).

Although the BNZONE is very likely to increase egg and chick survival, there is a high financial cost (Holzapfel et al. 2008). This is likely to be cost effective for small populations with slow recovery rates as these populations will benefit more from the project (Robertson 2004). However, as GSK kiwi populations recover and become self sustaining in the wild there will be less need for BNZONE as a management tool because other forms of management are likely to become more cost effective (Save the Kiwi 2011). Thus any new information on the reproductive rate and breeding behaviour of GSK and any improvements to the way eggs are collected may be important to help GSK populations recover as quickly as possible and reduce the financial cost of the BNZONE.

The objective of this report is to collate and analyse data that has been collected through the monitoring and research of two kiwi monitoring teams (Department of Conservation (Waimakariri office) and the Paparoa Wildlife Trust) to suggest improvements to the BNZONE project. This report assesses five main questions:

1. What proportion of great spotted kiwi eggs are incubated to full term in the wild?

2. Is there a difference in the number of great spotted kiwi eggs being incubated to full term at different times of the year and what are the lengths of incubation attempts?

3. What proportion of kiwi pairs will lay second eggs if the first egg is taken or unsuccessful in the wild and what proportion of these are incubated to full term?

4. What is the average time between the first egg being taken from the wild and the second egg being laid?

5. Is there a difference in daily activity of male and female GSK when incubating fertile eggs and how does daily activity change throughout the incubation period?

Methods

Study sites

Data on GSK has been collected from three different sites since 2007 (Paparoa Range on the West Coast of the South Island, Hawdon Valley in Arthurs Pass and Hurunui Valley north branch in the Hurunui District). All three sites have an elevation of around 600m. All are forested and sub alpine beech habitat (Nothofagus spp.). The Papaora Range also contains is a mixture of podocarp (Dacrycarpus spp.), rata (Metrosideros spp.), kamahi (Weinmannia racemosa) and Quintinia (Quintina spp.) and is likely to have a higher rain fall that the other two sites (G. Newton, pers. comm.). However small scale differences in habitat between the three sites have not been assessed.

The Paparoa Range has had eggs removed each year since the 2007/2008 season and the Hawdon Valley since the 2008/2009 season. However the Hurunui Valley North Branch has only had five eggs removed and only from the 2007/2008 and 2008/2009 seasons.

The Hawdon Valley has on-going extensive predator control with stoat trapping and sodium monofluoroacetate (1080) application. Predator control is largely applied when there is a beech mast year and predator numbers increase rapidly. The Paparoa Range has very minimal predator control and the Hurunui Valley north branch does not receive any predator control; however the Hurunui Valley has received limited 1080 use in the past.

Data collection/ Analysis

Some GSK in the study sites are fitted with VHF radio transmitters. Transmitters are attached to the leg of each bird and weigh around 23 grams each (Keye 2008). There are two variations of radio transmitters that have been used. This first is an “egg timer” transmitter which collects daily activity of the bird by recording whether the bird is moving each minute. This transmitter can store data for the previous seven days. The information from the transmitters can be heard as a series of beeps by a receiver. The beeps can be transmitted at 30, 48 or 80 pulses per minute which correlate with normal activity, incubating activity and mortality respectively. The second transmitter is a

"diagnostic" transmitter which is very similar to the "egg timer" although it can store up to 14 days of data. The diagnostic only transmits at 40 pulses per minute, meaning normal activity, and 80 pulses per minute, meaning mortality. If a transmitter detaches from a bird it will also transmit at 80 pulses per minute.

If a bird is incubating its daily activity will sharply decrease and stay low for the period of incubation. The daily activity of individual birds has been used to estimate the start date and end date of all incubations. Where eggs have been removed from the wild the age of the egg at removal has been used, as well as daily activity, to estimate the start date of incubation. Both the "egg timer" and the "diagnostic" transmitter can also be used to track a bird to its location, this way nest burrows can be found.

In this report, successful full term incubation has been defined as an incubation where the adult daily activity is low for at least 70 days and/or a chick has been found with the adult soon after an increase in the adult daily activity. When the daily activity of the parents is low for less than 70 days it is assumed that the egg has been unsuccessful in reaching full term (i.e. parents abandoned the egg, egg was predated on or egg was infertile). If an egg has not been incubated to full term, the end date of incubation can be estimated using the date where the incubating adults show a sharp increase in daily activity. Data has been collated from all three study sites and analysed using Microsoft Excel.

Results

1) The proportion of great spotted kiwi eggs in the wild incubated to full term

Data was used from all three study sites. However, any eggs which were removed from the wild for the BNZONE project have not been included in the analysis as the egg was not left in the wild for the full incubation period.

The proportion of great spotted kiwi eggs being incubated to full term in the wild was 0.29 (Table I). This suggests that only 29% of all eggs that are laid will actually hatch and 71% will be abandoned before full term incubation is reached. There is some variation between sites with the proportion from the Paparoa Range as low as 0.10 and the Hawdon Valley as high as 0.38. The largest sample size of 30 was collected from the Hurunui Valley north branch.

Table I: The proportion of great spotted kiwi eggs incubated to full term in the wild. Data from three different sites (Paparoa Range, Hawdon Valley, Hurunui Valley north branch), N= 10,8,30 respectively.

Sites	Proportion of eggs incubated to full term
All	0.29
Paparoa	0.10
Hawdon	0.38
Hurunui Nth Branch	0.33

2) The length of incubation of great spotted kiwi eggs at different times of the year

Data was used from all three study sites. Many of the Paparoa Range incubations were abandoned before 30 days, however not enough data was collected to estimate the exact date of abandonment so 29 days since the beginning of the incubation period has been used. However these incubations may have lasted a shorter time than 29 days. Where an egg has been incubated to full term but a hatch date for the egg is unable to be estimated from the daily activity of the parents, a 78 day incubation length has been used (S. Horan, pers. comm.). Eggs which have been removed for the BNZONE project have not

been included in the analysis as the eggs were not in the wild for the full incubation period.

There was no evidence to suggest a difference in the proportion of eggs going to full term at different times of the breeding season. (Fig. 1). There is large variation in the length of incubations between individuals and between different sites.

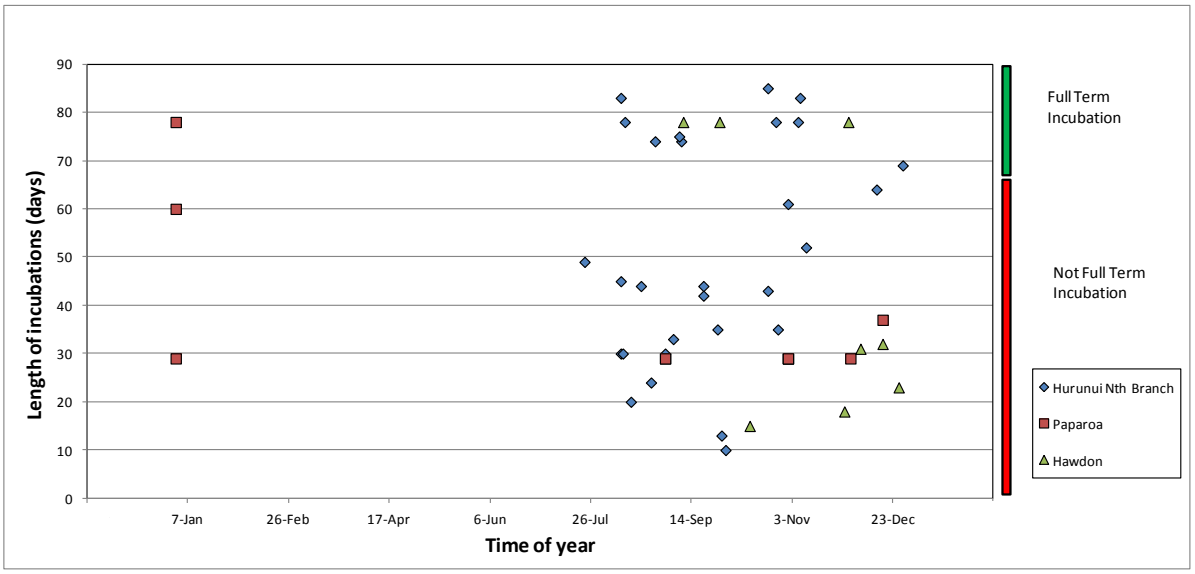

Figure 1: The length of great spotted kiwi incubation attempts (days) at different times of the breeding season for three different sites (Paparoa, Hawdon, Hurunui North Branch). N = 10,8,29 respectively.

3) Proportion of great spotted kiwi which lay a second egg if the first egg is taken or unsuccessful in the wild.

The proportion of great spotted kiwi pairs that will lay a second egg was calculated using information from pairs where the first egg was unsuccessful. The egg was either removed from the wild for the BNZONE project or did not reach full term due to natural causes (e.g. predation, abandonment by parents, infertile). The proportion of second laid eggs which reached full term incubation was also calculated. Data was used from all three study sites.

For all of the study sites combined 57% of eggs that were unsuccessful were replaced with a second egg (Table II). Only 23% of second laid eggs were incubated to

full term. There is some variation between sites with the Hurunui Valley north branch having both the highest proportion of second eggs and the highest proportion of second eggs being incubated to full term.

Table II: The proportion of great spotted kiwi pairs which lay a second egg after their first egg was unsuccessful from three study sites (Paparoa Range, Hawdon Valley, Hurunui Valley north branch). N = 28, 18, 17 respectively. The proportion of second laid eggs which were incubated to full term has also been calculated. N = 8, 4, 10 respectively.

Sites	Proportion of adults which lay a second egg	Proportion of second laid eggs incubated to full term
All	0.57	0.23
Paparoa Range	0.50	0.13
Hawdon Valley	0.50	0.00
Hurunui Valley Nth Branch	0.76	0.40

4) Time between the first egg being taken from the wild for the BNZONE project and the second egg being laid

The average number of days between the first egg being removed from the wild for the BNZONE project and the beginning of incubation of the second laid egg was calculated using data from eggs from all three study sites. Data was not used where eggs were unsuccessful due to natural causes as the exact date where adults stop incubating is difficult to estimate and less accurate than eggs which have been removed for the BNZONE project. Only data where a second incubation attempt has occurred was included in the analysis.

The average number of days between an incubating adult's first egg being taken and the beginning of a second incubation attempt was 60 ± 11days (Fig. 2). The Paparoa Range showed a significantly longer time of 73 ± 6 days between the first egg being removed and a second incubation attempt (P = 0.0026).

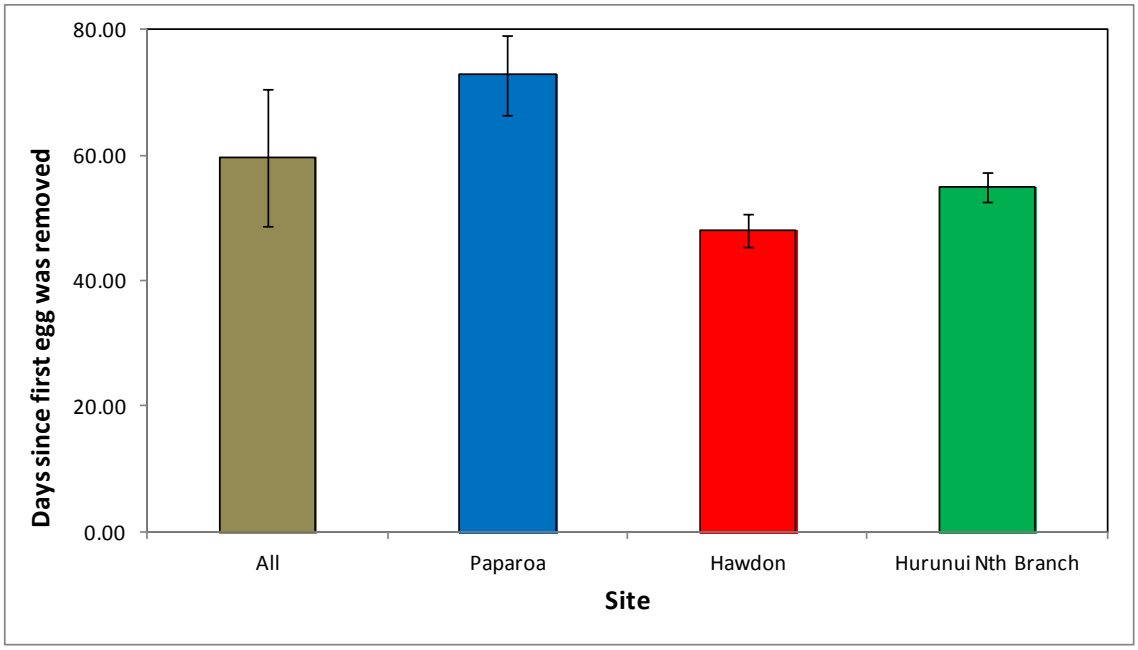

Figure 2: The time between the first egg being removed from the wild for the BNZONE project and the beginning of a second incubation attempt for three different sites (Paparoa Range, Hawdon Valley and Hurunui Valley North Branch). N = 8,9,3 respectively. Error bars represent the standard error of the means.

5) Difference in daily activity of male and female great spotted kiwi incubating fertile eggs

The average daily activity for males and females incubating eggs was calculated using data from two different sites (Hawdon Valley and Hurunui Valley North Branch). Only the activity of males and females incubating eggs that were removed from the wild for the BNZONE project are included in the average because of the difficulty in retrieving eggs that have been abandoned in the wild. The average daily activity has been divided into weeks since the beginning of the incubation period. Any week where there was less than ten days of recorded activity, or less than six individual kiwi had activity recorded in that week, have not been included in the analysis.

Incubating female kiwi had significantly higher daily activity than males for weeks 1, 2, 3, 4 and 5 (Fig. 3, Table III). Daily activity corresponds to the time an individual spends incubating, thus for the first five weeks of incubation the males tend

to spend 1 – 1.5 hours longer incubating than the female. Daily activity tended to decrease over time for both males and females. The least squares regression line for males is y = -0.2451x + 7.4378, R^2 = 0.7106, and females is y = 0.33x + 8.7168, R^2 = 0.8972.

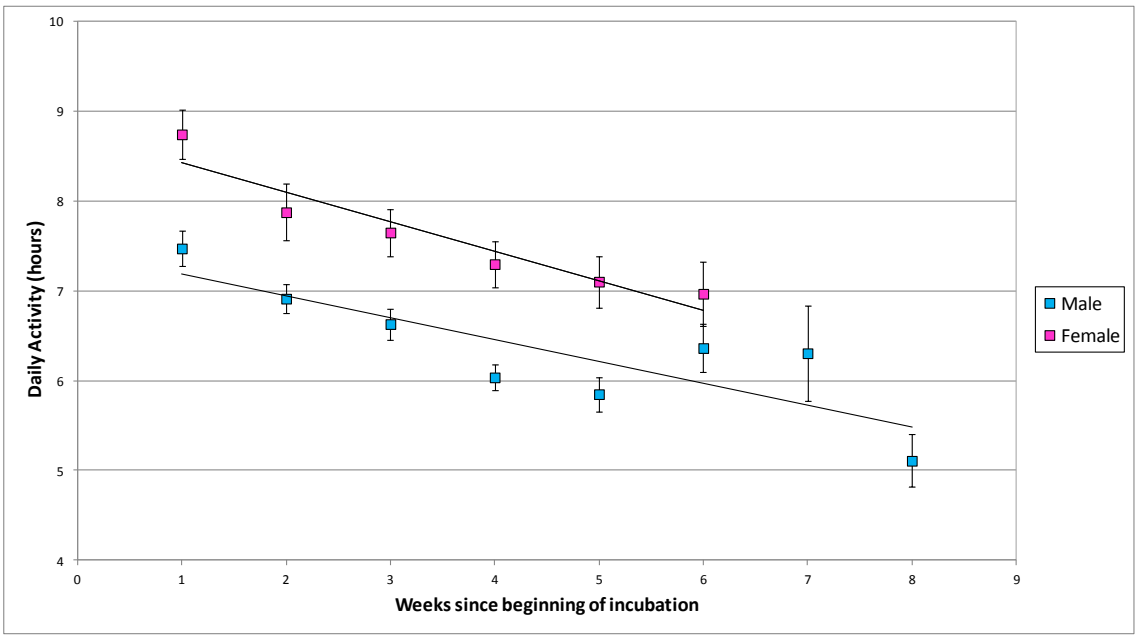

Figure 3: Average daily activity of male and female great spotted kiwi incubating fertile eggs from two different sites (Hawdon and Hurunui North Branch). N = minimum of 10 activity days per week and a minimum of six individual kiwi.

Table III: t-test between the daily activity of male and female incubating kiwi for consecutive weeks since the beginning of the incubation period.

	Male		Female			
Week	**Daily Activity**	**SD**	**Daily Activity**	**SD**	**df**	**p - value**
1	448.37	137.76	523.69	148.9	164	0.000225
2	414.81	100.81	472.59	140.43	89	0.00677
3	397.84	102.56	459.03	132.51	129	0.00142
4	362.19	90.06	437.9	119.89	102	0.0000382
5	350.99	103.33	426.17	117.61	86	0.000461
6	381.8	112.95	418.1	98.77	43	0.183

Discussion

This report collated current monitoring data from the Paparoa Wildlife Trust and the Department of Conservation, Waimakariri Office, to improve knowledge of GSK reproductive rate and breeding behaviour and suggest improvements to the BNZONE project.

Interestingly only 29% of GSK eggs that were laid were incubated to full term in the wild. This is similar to McLennan et al. (1996) who found 37% of GSK eggs that were laid hatched. Small sample sizes produce some uncertainty in the actual percentage. McLennan et al. used data from only 19 eggs and from different areas, (Paparoa Range and Rotoiti) whereas this study has a sample size of 48 eggs with the majority coming from the Hurunui Valley North Branch. Some of the data in this study was included from sites where the BNZONE is in place. These sites produce less reliable data because because eggs which are unsuccessful in the wild early in incubation are not available to be removed for the BNZONE. This can skew the data towards a higher proportion of wild eggs being unsuccessful. To date 68 GSK eggs have been collected from the wild for the BNZONE and have a 79% hatching success (M. Wiley, pers. Comm.). Thus eggs incubated for the BNZONE have a much greater chance of hatching than eggs left in the wild.

The Hawdon Valley had the greatest percentage (38%) of eggs incubated to full term. Extensive predator control has been undertaken in the Hawdon Valley; whereas the Paparoa Valley and the Hurunui Valley North Branch have had little to no predator control. Therefore the results suggest that predator control may increase the proportion of eggs that are incubated to full term. Predators can affect hatching success both by predating on eggs and increasing disturbance to the nest burrow causing kiwi to abandon their nests (McLennan et al.1996). Nevertheless with only a small sample size from the Hawdon Valley, further investigation into the proportion of eggs that are incubated to full term in the wild with predator control should be investigated.

The Willowbank Wildlife Reserve in Christchurch incubate eggs that are removed from the wild (S. Horan, pers. comm.). It is beneficial for Willowbank to have eggs earlier in the season than later in the season (S. Horan, pers. comm.). There was no evidence to suggest that eggs will only go to full term at a certain time of the breeding

season. The knowledge that incubations later in the season are just as likely to be incubated to full term suggests that removing eggs early in the season would not impact the population to a greater extent than if eggs were removed later in the season. Nevertheless caution is required as chick survival is unknown in the wild and chicks which hatch later in the season may have a lower chance of survival because of differences in weather or food resources. Verhulst & Neilssen (2008) showed that, in general, the time of the breeding season that an egg is laid is important in reproductive success, so it would be beneficial if further research was undertaken into the time of hatching and chick survival in the GSK.

Unsuccessful incubations could last as short as 10 days to as long as 62 days. Therefore eggs should be removed as early as possible because BNZONE incubated eggs are more likely to be successful in reaching full term. Nevertheless there is a trade off when collecting eggs early in development because less developed eggs are more likely to get damaged during transportation. There is only a 1% probability of a kiwi egg hatching if the egg is removed from the wild before 10 days and only a 20% probability if the egg is removed between 10 and 20 days old (Save the kiwi 2011). However there is a 75% probability of the egg hatching if it is removed from the wild at 30 days (Save the kiwi 2011). Although these percentages are based on all kiwi species, the current aim to collect great spotted kiwi eggs at 30 days old is still appropriate (S. Horan, pers. comm.).

GSK have the potential to lay a second egg in the same season. 57% of kiwi, where the first egg was unsuccessful, laid a second egg later in the season. This suggests that if eggs are removed from the wild for the BNZONE then 57% of breeding adults will lay a second egg, thus removing some eggs for the BNZONE is actually increasing the total number of eggs laid for that season. Second laid eggs had a 23% probability of being incubated to full term, only marginally lower than the 29% of all eggs being incubated to full term. Nevertheless with only a small sample size, more information is needed to confirm that there is no difference in the probability of second eggs being incubated to full term.

The percentage of kiwi that laid a second egg after their first was unsuccessful varied with site. The Hurunui Valley North Branch showed that 78% of kiwi laid a

second egg. The Hurunui also had the highest percentage (40%) of second eggs being incubated to full term. This variation could be due to differences in food availability. Female brown kiwi (A. mantelli) need to invest an additional 4014KJ of energy into a second egg (Calder et al. 1977). If GSK are unable to feed on high energy foods then they may not be able to gain enough energy to lay a second egg. All three sites contain beech forest habitat (Fagus spp.) and sub alpine habitat, unfortunately no habitat or food availability studies have been undertaken in any of the study sites so food availability cannot be compared. Nevertheless the results suggest that impacts created by the removal of eggs for the BNZONE will vary with source population.

It takes around 60 ± 11days for a female kiwi to lay a second egg after the first egg has been unsuccessful. GSK use stored energy reserves which they have accumulated over time to produce eggs (McLennan 1988), and yolk deposition is thought to need at least 25 – 30 days (Calder 1979). However this information was calculated using weights of brown kiwi where the female does not partake in incubating the egg. Nevertheless females may be able to produce another egg with very little additional energetic cost; however it may take time to build up these reserves. It is possible that female GSK need around 60 days to gain enough energy reserves from feeding to produce the second egg. It is also possible that the laying of an egg is restricted by the development time of the egg. However there is little information on the length of time that eggs need for development before they are laid (Keye 2008).

The Paparoa Range showed a significantly longer time of 73 ± 6 days between the first egg being removed and a second incubation attempt. This difference between the sites could be due lower food availability or different weather conditions in the Paparoa Range compared to the other two sites as it is very likely that the Paparoa range receives a higher rainfall than the other sites (G. Newton, pers. comm.). However no studies on food availability or weather have been undertaken in any of the study sites.

GSK are unique in that both the male and the female are involved with incubating the egg. Incubating females have higher daily activity than males which corresponds to females incubating for a shorter time each day than males. This is understandable as females invest a lot of energy already into the development of the egg (Calder et al. 1977) and may need a longer time to feed each day to replace the invested

energy. Interestingly, there is a negative trend of daily activity and increasing weeks of incubation for both the incubating male and female. This suggests that as incubation proceeds, parents are willing to invest more energy.

Future Research

From this analysis it is easy to see that there is very limited knowledge about the reproductive success and breeding behaviour of GSK. It would be beneficial to the species to fully understand the hatch rate of eggs and survival rate of chicks which are left in the wild in both predator controlled and predator uncontrolled sites. As the BNZONE is seen as a temporary measure to rapidly increase GSK abundance to a self sustaining level (Save the Kiwi 2011), it is also important to know how effective other types of management might be. This information could be gathered by measuring the hatch rate of the wild incubated eggs in the Hawdon Valley, where predator control is currently undertaken, with that of the Paparoa Range or Hurunui Valley North Branch where there is no predator control, and monitoring them through different life stages.

Second laid eggs have a similar probability of being incubated to full term than first laid eggs, however the sample size was relatively low and more information is needed to confirm this. Confirmation of this may change the way eggs are collected from the wild. If a second laid egg was found to have a much lower chance of being incubated to full term in the wild, then it would be more appropriate for the BNZONE to remove both first and second laid eggs from the wild for the same kiwi pair. Furthermore to reduce the impact of egg collection on the source population and allow for further research and monitoring some of the first laid eggs could then be left in the wild. However, since Willowbank, who incubate the removed eggs, prefer eggs earlier in the season, if no difference in hatch rate is confirmed between the first laid egg and the second laid egg then it may be more beneficial for the BNZONE to remove all of the first laid eggs. The second laid eggs, which would be laid later in the season, could then be left in the wild to reduce the impact on the source population and allow for continued research and monitoring.

Finally it would be beneficial to know habitat and food availability for all of the study sites to allow for differences to be compared. The benefits of BNZONE are likely

to vary depending on the site (e.g. food availability and predator control). Therefore the benefit of the BNZONE for a population of GSK should be assessed independently for each site.

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