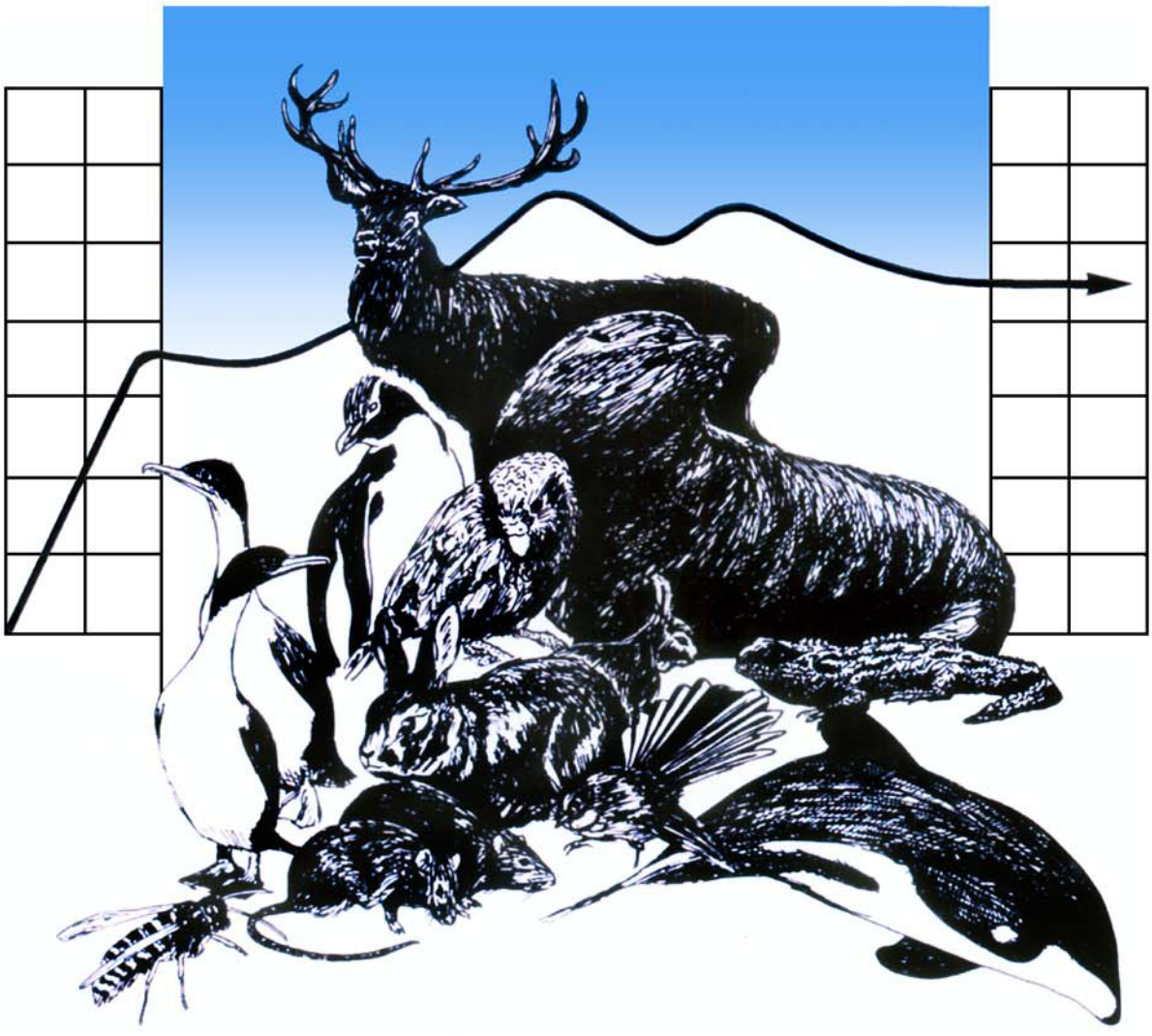
UNIVERSITY of OTAGO

Te Whare Wānanga o Otāgo

NEW ZEALAND

DEPARTMENT OF ZOOLOGY



WILDLIFE MANAGEMENT

Emergence behaviour in a captive population of Hochstetter's frog (Leiopelma Hochstetteri) at Hamilton Zoo: A trial of recording methods.

Emma Shaw

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

University of Otago

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Practice of Wildlife Management

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Executive Summary

In New Zealand, the conservation of amphibians is especially important as its unique endemic genus of Leiopelma is considered to be one of the most primitive, endangered and evolutionarily distinct in the world.

As part of their continued conservation strategy, the Native Frog Recovery Group has identified the need for captive populations to be established for all Leiopelma species. In line with this goal, a population of 45 Hochstetter's frogs was set up at Hamilton Zoo in 2006. However, significant mortalities have meant that the current population stands at 21 individuals. In order to act as it was intended; as an insurance population, a source of valuable research opportunities and as a key advocacy tool for the species, the colony must first be able to survive. Currently, the most pervasive disease afflicting the colony is nutritional metabolic bone disease. Little is understood about the proximate causes of this disease in L. hochstetteri, but a lack of UVB exposure due to the shaded enclosure may be one of them.

The aim of this study investigated two different methods to film this species, which had previously never been studied using film. The aim was to gather data on the emergence behaviour of L. hochstetteri, especially in regards to diurnal emergence and possible exposure to UVB.

While neither study detected any frog emergence, the project proved to be a valuable exercise in terms of evaluating the two methods, enabling a clearer understanding of what would be more effective in future studies. Much more research is required into the behaviour of both L. hochstetteri and the other Leiopelmatids and as filming is likely to be one of the more efficient ways of conducting such studies, further research into filming methods is also necessary.

Contents

1.0 Introduction

Since 1989 it has been widely recognised that amphibians are undergoing severe global range contractions, population declines, and species extinctions (Stuart et al. 2004, Lips et al. 2005). These trends have no single common cause, but some have been linked to global climate change (Gardner 2001), pathogens and disease (Laurance et al. 1996), pollution, habitat loss and modification and invasive species (Baber and Babbitt 2003). Conservation of amphibian species is important for many reasons, including their often vital role in ecosystem processes, and their role as indicators of ecosystem health (Blaustein and Wake 1990, Barinaga 1990).

Conservation of amphibians is especially important in New Zealand (Newman 1996), as its unique endemic genus of Leiopelma is considered to be one of the most primitive in the world (Bell 2004,); having diverged with its closest living relatives, Ascaphus, around 200 million years ago and with all other living frogs 50 million years before this (Roelants et al. 2007).

Since the arrival of humans in New Zealand, three of the seven known Leiopelma species have become extinct: Leiopelma waitomoensis, Leiopelma markhami, and Leiopelma auroraensis (Worthy 1987, Newman 1996), while the four remaining species; Archey's frog (Leiopelma archeyi), Hamilton's frog (Leiopelma hamiltoni), Maud Island frog (Leiopelma pakeka) and Hochstetter's frog (Leiopelma hochstetteri), have suffered significant declines in range and population size (Bell et al. 2004, Daugherty et al. 1994, Worthy 1987).

Introduced mammalian predators, which are presumed to have caused the three known leiopelmatid extinctions (Worthy 1987), may still pose a significant threat to the four extant species (Baber et al. 2008, Haigh et al. 2007, Najera-Hillman et al. 2009).They are also threatened by continuing habitat destruction (Najera-Hillman et al 2009), introduced disease (Bell et al. 2004), fragmentation of populations and the risks of decline associated with small

populations due to environmental and demographic stochasticity and inbreeding depression, which are enhanced by the species' small home range and clutch size (Waldman and Tocher 1998, Berger et al. 1998, Newman 1996, Waldman and McKinnon 1993).

All four Leiopelma species are ranked within the top 60 evolutionarily distinct and globally endangered amphibians of the world (Zoological Society of London 2010); and under New Zealand's current threat classification system lists Hamilton's and Archey's frogs as Nationally Critical, Maud Island frogs as Nationally Endangered, and Hochstetter's frogs as sparse (Hitchmough et al. 2007).

This project will focus on Leiopelma hochstetteri, which is a small (Snout-Vent Length <48 mm), highly cryptic species, being unique within the Leiopelmatids in that they are semi-aquatic, living in crevices and under rocks logs and leaf litter near streams and seepages, whereas the other species are almost completely terrestrial (Bell 1985, Bell et al. 1985). Currently the most widespread and abundant of the four Leiopelmatids, scattered populations of L. hochstetteri are found naturally in the northern half of the North Island above lake Taupo, and on Great Barrier Island (Baber et al. 2006, Crossland et al. 2005, Fouquet et al. 2010).

The total population size for this species is currently estimated to be 100,000 (Bishop et al. 2009 (in review)) but this estimate, and others made for the other three Leiopelma species, should be approached with caution (Crossland et al. 2005).

Regardless of the large population size, relative abundance and low threat classification of L. hochstetteri compared to the other Leiopelmatidae, there is a strong necessity for continuing research and increased conservation measures to be put in place for this species. The discovery of L. hochstetteri on Mt Maungatautari by Baber et al. in 2006 has highlighted a significant lack of knowledge about its current distribution (Fouquet et al. 2010a) and due to the geographic and genetic distinctions between many of its populations, recent studies have

called for the species to be conserved as at least 13 different "Evolutionarily Significant Units" (Fouquet et al. 2010a, Green 1994, Gemmel et al. 2003).

As part of their continued conservation strategy, the Native Frog Recovery Group has identified the need for captive populations to be established for all Leiopelma species (Newman 1996, Bishop et al. 2009 in review). Captive management can be used not only as a tool for direct conservation of populations, but as a valuable resource for practical research, which can also provide an accessible opportunity for advocacy (Griffiths and Pajaveau 2008). In line with this, a captive population of 45 L. hochstetteri was established at Hamilton Zoo in 2006, to provide an insurance population against the risks of decline in the wild, and so that captive breeding techniques could be developed (Webster 2004).

Unfortunately, the captive population has suffered a significant number of mortalities since it began and currently (as of January 2010) stands at 20 frogs (Goddard pers. comm. 2009). The cause of many of the early L. hochstetteri mortalities are reviewed by Shaw and Hozapfel (2008).

There has also been a lack of successful breeding at the facility, although egg clusters (both non-fertile and fertile) have been produced, the latest producing tadpoles which failed to develop (Beauchamp et al. 2010).

For this captive breeding programme to remain viable, it is vital that the rate of mortality seen in the population is substantially diminished, and that viable offspring are produced.

One of the current issues facing the captive population of L. hochstetteri at Hamilton Zoo is the development of Nutritional Metabolic Bone Disease (NMBD), which has been noted in 9 individuals (Haigh et al. 2010). This disease is also prevalent in captive Leiopelma archeyi populations at both Auckland Zoo and The University of Otago, with symptoms presenting as asymmetrical jaws, broken bones, and overall loss of bone density.

Many cases of amphibian NMBD develop through a lack of dietary calcium or calcium assimilation through deficiencies in calcitrol, which causes depletion of skeletal calcium stores, or limited absorption of phosphates needed for bone mineralization, which leads to bone weakening (Densmore and Green, 2007, Antwis and Brown 2009). It can also be caused by inadequate levels of UV-B exposure, leading to reduced synthesis of calcitrol and poor calcium uptake from the intestine (Holick 2003, Densmore and Green 2007).

As the process of calcium and phosphate regulation in L. hochstetteri is yet to be studied, the cause of NMBD in these species has not yet been determined.

When the captive enclosures for L. hochstetteri and L. archeyi were constructed it was assumed that captive Leiopelma species would not require any form of UV light (Webster 2004) as they are primarily a nocturnal species. However, while there is a paucity of studies into the timing of emergence in these species, daytime activity has been recorded. Bell (1978) indicated that captive L. archeyi and L. hochstetteri show some daytime activity, and were occasionally seen during the daytime in the wild and accordingly, Cree (1989) found that on wet days following wet nights, some wild L. archeyi would remain emerged well into daylight hours, although most returned to retreat sites before dusk. Whitaker and Hardy (1985) also observed diurnal L. hochstetteri emergence on Great Barrier Island.

If these species do require UV-B light, normally provided by diurnal emergence, to endogenously photosynthesise vitamin D_3, inadequate UV-B light exposure in captivity could lead to poor calcium and phosphorus metabolism, and the development of NMBD (Densmore and Green 2007).

While L. archeyi at Auckland Zoo were provided with 1-2 $\mu W/cm^2$ UV-B following a brief investigation into the potential exposure of wild L. archeyi to UV-B light (Webster 2004), captive L. hochstetteri do not receive supplementary UV-B light, and the roof of their enclosure may limit natural UV-B exposure.

The aim of this project is to film the frogs in captivity, in order to add to the current knowledge of L. hochstetteri emergence behaviour, and to examine whether diurnal emergence may coincide with UVB exposure. To date, there have been no studies of L. hochstetteri behaviour made using film, nor any published studies on any of the Leiopelmatids that have used recorded media to observe behaviour.

2.0 The captive frog enclosure at Hamilton Zoo

Leiopelma hochstetteri at Hamilton zoo are maintained within three separate cells measuring 2x2m with each cell containing a running stream, where soil, gravel and large stones provide the frogs with daytime retreat sites (Beauchamp et a1. 2010). These pens are surrounded by predator proof mesh, and covered by a roof. Sprinklers in the pens are connected to a tank fed by rain water, so that rainfall in the cells corresponds with rain outside the enclosure. The outer side of the enclosure closest to the pens is planted with trees. When the project first began, Cell One housed 9 frogs, all of which had NMBD, Cell Two housed 7 frogs and Cell Three housed 5 frogs.

3.0 First Film Trial

In November 2008, Canon presented Hamilton Zoo with an HV30 High definition video camera, so that the behaviour of captive L. hochstetteri could be studied. This project was undertaken to make use of this equipment.

3.1 Materials and methods

Between June 21 and July 9 2009, the three frog cells were filmed using the HV30 camera, connected to a Panasonic VCR/DVD recorder, recording onto standard 3 hour VCR tapes, set to record on Long play, giving 9 hours of recording time.

The hours that were able to be filmed were restricted by the length of the tapes and the Zoo's opening and closing hours (8am-5pm) during which the tapes could be changed. Under these restrictions and with the aim to film each of the 24 hours in the day for as long as possible,

the regime in figure 1 was set up. Each of the three cells was filmed as it was not known whether emergence would differ between frogs with and without NMBD.

Time																				Hours filmed
1:00		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
2:00		1		1	1		1	1			1	1	1	1	1			1	1	12
3:00		1			1		1	1				1		1	1				1	8
4:00		1			1		1	1				1		1	1				1	8
5:00		1			1		1	1				1		1	1				1	8
6:00		1			1		1	1				1		1	1				1	8
7:00		1			1		1	1				1		1	1				1	8
8:00		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		16
9:00		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		16
10:00		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		16
11:00		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		16
12:00		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		16
13:00		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		16
14:00		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		16
15:00		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		16
16:00		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		16
17:00		1			1			1	1			1			1	1				7
18:00		1	1		1			1	1	1		1			1	1	1			10
19:00		1	1		1			1	1	1		1			1	1	1			10
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21:00		1	1		1			1	1	1		1			1	1	1			10
22:00		1	1		1			1	1	1		1			1	1	1			10
23:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		18
0:00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		18
Date	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	
	June										July									
		Cell 1						Cell 2						Cell 3						

Fig 1. Film regime and the total number of hours filmed between June 21 and July 9, 2009.

During recording the video camera was set up on a tripod positioned outside the cell, at a height of about 1.5 meters (Figure 2.), so that as much of the enclosure as possible was visible, making sure that the most common retreat sites in each cell (Goddard Pers. Comm. 2009) were included in the frame.

The position of the camera was not moved during the filming of each separate cell, but cell changes were made at 08:00 hours on 28 June (between cell One and Two) and 4 July (between Cell Two and Three). Tapes were changed at 08:00 and 17:00 every day during filming, and the timer function on the VCR was used to set recording after 17:00.

During night time recording, a small lamp with a 40watt bulb, covered by red cellophane to dull the intensity of the light, was used give extra illumination to the cells (Figure 2)

Figure 2. Showing the recording set up for the first film trial, with the camera, VCR and lamp set up at the front of Cell Three.

Recorded tapes were watched on fast forward, then on real time, with any movements that may have been frogs being noted down and watched again. The timing and duration of the sprinkler system activation was also noted.

Water temperature, air temperature and relative humidity in each cell were recorded using a Tidbit and Hobo logger, consecutively, so that the relationship between emergence and these parameters could be examined.

On June 13 and 14, UVB readings were taken within each cell at 08:00 and again at 14:00, using a Solartech Solarmeter 6.2 UV Meter. Readings were taken by scanning the UVB meter over the cell just above ground level.

3.2 Results

After watching all of the tapes at least twice on normal speed (9hours), frog emergence was not noted during either day or night time recording.

The sprinkler system was on for more than 14 hours during filming.

As no emergence was seen, it could not be linked to hourly ambient water and air temperature data or to relative humidity, so only general data is given. Due to an error, temperatures could not be recorded from 2-8 July. Water temperature, air temperature and relative humidity data from Cell One between 21 June and 1 July is shown in table 1.

No positive UVB values were recorded during UVB testing, but afterwards, direct sunlight was filmed in the cells between the hours of 13:00 and 15:00 on 7 days.

	Water Temperature	Air temperature	Relative Humidity
Mean	10.76°C ± 0.8055	8.32°C ± 2.33	94.24% ± 4.79
Maximum	16.51°C	16.53 °C	98.54%
Minimum	9.26°C	2.71 °C	82.45%

Table 1. Mean, maximum and minimum values for air temperature, water temperature and relative humidity in Cell One between June 21 and July 1 2009

3.3 Discussion

The lack of detected emergence during this study could have had multiple causes. Firstly it is possible that the frogs did not emerge at any time during filming. This could be explained by the fact that the trial was conducted during winter months when the frogs may be less active. While data collected by Goddard (2009 unpublished) indicates that emergence of L. hochstetteri at Hamilton Zoo has previously occurred in the cells at a minimum overnight

temperature of -1°C, it also shows a strong positive relationship between emergence and temperature, with most frogs emerging at minimum overnight temperatures above 5°C. This indicates that it would be more likely for the frogs to emerge on nights that were warmer than those experienced during the film trial (Table 1).

To date, no diurnal emergence has been recorded at Hamilton zoo and the frogs are generally thought of as being nocturnal (Bell 1978) so it is possible that none were seen during the daytime because they did not emerge. The possibility exists that the set up of the camera and light may have disturbed the frogs to such an extent that they did not emerge, but as frogs have been seen to emerge very close to human activity in the wild (Shaw, personal observation 2010) this is considered unlikely.

The second possibility is that the frogs did emerge but were not seen due to:

1. Poor visibility during filming. While visibility during the day time was very good, it is possible that frog emergence may have occurred and been missed during the sprinkler being on, or at night if they emerged in a particularly dark shadow.
2. Emergence occurring in an obscured place, such as behind a log or rock, or outside the angle of the camera.
3. Frogs may have emerged in cells that were not being filmed, so emergence was missed.

It was presumed that that the frogs would be quite visible if emergence did occur, due to their slow locomotion and tendency to position themselves on the top of rocks when emerged (Goddard pers. Comm. 2009).

While no positive UVB measurements were observed on the days measured as they were overcast, the direct, albeit dappled sunlight filmed in the enclosures indicates the potential for the frogs to be exposed to >2 $\mu W/cm^2$ UVB on most sunny days, if emergence did occur,

which equates to the UVB exposure given to the captive L. archeyi at Auckland Zoo (Webster 2004).

As of January 2010, no further cases of NMBD have been noted in the captive L. hochstetteri at Hamilton zoo, following identification of the 9 initial cases. This may indicate that if the initial cause of the NMBD in these frogs was caused by a lack of UVB exposure in the enclosures in which they were previously held, they are now receiving enough light to prevent further cases developing, although this cannot be proven.

4.0Second Film Trial

As no frog emergence was detected in the June-July filming session, it was decided that a summer recording session should be made when the frogs might be more active, and if possible, using a more efficient method of filming.

4.1 Materials and methods

HandyAvi4.3 computer software by **AZcendant®** has a motion sensing function that can be used in conjunction with a webcam, to record separate frames when there is movement, which will play together as a film. This seemed like a much more efficient alternative to filming with a video camera and VCR, as the computer could be left running for continuous recording.

Between December 6, 2009 and January 19, 2010, Cell One was filmed during daylight hours (as the camera could not detect movement at night) using a ColorVis PC webcam in conjunction with an HP Compaq nx6210 laptop and using the Motion Sensing function in the HandyAvi 4.3 software.

The film was set in HandyAvi to record at 640x 480 megapixels and at 30 frames per second, and play back at 20 frames per second. The recorded films were watched on VCL Media Player, at 0.5 speed, then at 0.13 speed, then finally frame by frame.

It was decided that it would be best to film a single cell, to avoid missing possible emergence through shifting the camera, and as Cell One had the most frogs, this cell was filmed for the duration of the second trial.

During filming, the webcam was clipped to the edge of the Cell (Figure 3). The webcam only recorded between sunrise and sunset (Table 2), as there was not enough light given out by the webcam at night to activate recording.

Again, water temperature and relative humidity in each cell was recorded hourly using Tidbit and Hobo loggers.

The presence and timing of any direct sunlight that fell on the floor of the cells was noted.

Part A

From December 6 -13 Cell One was filmed with the webcam clipped to the front of the cell (Figure 3) using a sensitivity level of 30.

The webcam was placed so that the most commonly used retreat sites were in focus.

Part B

From December 14 - 20 Cell One was filmed with the webcam in the same position, using a sensitivity level of 20, so that fewer frames were recorded.

Part C

From January 2 -9 Cell One was filmed with the webcam in the same position, using a sensitivity level of 15.

Part D

From January 11-19, Cell One was filmed using a sensitivity level of 20. The webcam was moved to the upper right hand side of the cell (Figure 3) so that it focussed on the upper right corner, where what looked like frog movement had been seen in the film from part C. The sensitivity was increased so that more frames would be recorded.

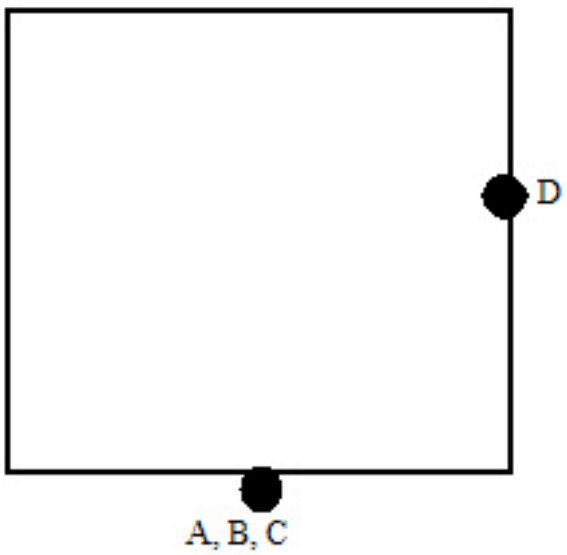

Figure 3. Indicating the position of the webcam for Parts A, B, C and D of the second film trial.

4.2 Results

While the length of time that each separate recording event ran for was similar, the number of frames recorded varied widely (Table 2). This was due to both the different sensitivity that the software was set to record at, but also by the level of wind, which caused the shadows in the enclosure to trigger filming.

In all parts, there were many "non-shadow" movements, most of which were obviously insects as they were too small to be frogs. In parts B, C and D, movements that were more likely to have been frogs (due to their size) were recorded. In part D and C especially, jumping movements were noted against the side of the enclosure (Table 2). Unfortunately, due to the quality of the camera and the nature of the motion sensing recording, it was difficult to get a clear view of what was making the movements.

Initially, it was decided some of the movements in part C must have been frogs rather than insects, but after many days of reviewing this footage and reviewing the movements in part C, it was decided that all the movements seen were just large crickets that had survived in the

enclosure after being fed to the frogs. This opinion was strengthened after observing the jumping behaviour of wild L. hochstetteri.

Water and air temperature, as well as relative humidity was able to be recorded throughout the entire filming period in this trial (Table 3). As expected, both water and air temperature was much higher than in the first film trial and relative humidity was lower (Table 1). Again, as none was detected, the relationship between emergence and these environmental variables could not be determined.

Direct sunlight was seen in the cell from 09:00 to 17:00 on all of the days which were recorded.

Part	Days filmed	Total hours filmed	Mean hours filmed per day	Total frames recorded	Average recording start time	Average recording finish time	Possible episodes of "frog-not-insect" movements
A	8	86.71	12.35	62567	07:19	19:54	2
B	7	85.6	12.13	60436	06:40	18:53	1
C	8	91.9	11.29	1681	07:56	19:25	6
D	9	107.36	11.55	108087	07:43	19:39	2

Table 2. Showing recording information for the four parts of recording between December 6, 2009 and January 19, 2010.

	Water Temperature	Air temperature	Relative Humidity
Mean	15.78°C ± 0.45	16.64°C ±1.87	84.64% ± 8.56
Maximum	18.22°C	22.27°C	97.75%
Minimum	14.60°C	11.66 °C	50.76%

Table 3. Mean, maximum and minimum values for air temperature, water temperature and relative humidity on the days of recording between December 6, 2009 and January 19, 2010.

4.3 Discussion

As in for the first film trial, the reason diurnal frog emergence may not have been detected could have been because it did not occur, or was missed if it did. It was thought that the warmer climate (Table 3) may mean that frogs would be more active, but nocturnal activity could not be compared to the first filming trial, because the camera did not function in the dark. Currently there is no data on the diurnal emergence of the frogs at Hamilton Zoo.

It is possible that as all of the frogs in Cell One had NMBD, they may have been less active and less likely to have appeared diurnally, though Goddard (2009, Pers. Comm.) has stated that they appear to show similar levels of mobility to healthy frogs.

It is important to note that the author has personally seen three separate examples of diurnal emergence in wild L. hochstetteri, in May, October and November 2010. In these cases, all frogs appeared to be healthy. These observations, alongside those of others (Bell 1978, Whitaker and Hardy 1985) indicates that L. hochstetteri may emerge diurnally more frequently than previously thought, highlighting the need for future long term emergence monitoring of this and other Leiopelma species.

Although most L. hochstetteri habitats are very shaded by trees (Najera-Hillman et al. 2010, Fouquet et al. 2010b) there are commonly patches where direct sunlight reach the rocks and logs that this species utilises for retreat sites. Direct sunlight was seen in the frog enclosure on all of the filmed days for at least 8 hours per day during this trial, indicating that in summer at least, if frogs emerge they may receive levels of UVB exposure similar to that found in their natural habitat. In the first film trial in winter, the duration of sunlight in the enclosure was much shorter, and it is possible that sun exposure may have been limited by the roof, due to the angle of the sun during this season. It is recommended that future enclosures have a roofing system that allows at least some patches of the natural spectrum of

light to reach the floor of the enclosures all year round, so that if UVB exposure plays an important part in calcium regulation (or other behavioural and physiological cycles) (Pough 2007, Antwis and Brown 2009) in this species, further cases of disease can be prevented.

5.0Conclusion

While neither of these filming projects was successful in terms of adding to the knowledge of L. hochstetteri emergence behaviour in relation to UVB exposure through direct observation of emergence, some important information on the efficacy of filming these frogs was gathered. While all such filming studies of native frog behaviour, especially in situ will always be complicated due to their small, cryptic nature and exhausting due to the time it takes to watch the footage, it is likely that remote recording will be more cost effective than personal observation of frogs over an equivalent period of time.

It is therefore important that further studies of Leiopelmatid behaviour are made using filming, as there is still a vast amount of information lacking in regards to the natural history of these species (Bishop et al. 2009, Bell 1978, Fouquet et al. 2010b). Aside from emergence, such studies may be able to observe behaviour such as amplexus and egg-laying, document the relationship between emergence and seasonal changes and provide important information on feeding behaviour. It would also be beneficial to be able to study whether the behaviour of captive and wild frogs differs, as has been seen before in terms of emergence in captive Leiopelmatids (Bell 1978).

Having quality videos of natural frog emergence and behaviour would also be very valuable for education and advocacy at zoos and for other institutions such as DOC visitor centres. This is because it is very unlikely that people visiting enclosures where native frogs are held, or areas where native frogs naturally occur, would ever see natural emergence and education

will play an essential part in the continuing conservation of these precious species (Bishop et al. 2009, Griffiths and Pajaveau 2008).

6.0Overall evaluation of filming methods

While both of these methods had significant drawbacks, it would be possible to use elements of each in future film trials and it is important to take note of the problems encountered in these trials when planning future research.

Video and VCR

- Filming was intensive due changing the tapes twice a day.
- Good image quality for day time filming. Night time image quality would be vastly improved by the use of an extra Infrared light, which can be purchased for the Canon camera.
- Ability to film much of the enclosure reduced chance of missing emergence.
- Inexpensive (VCR tapes $5-$15).
- Very time consuming (months) due to the need to watch in real-time so that no movements were missed.
- Would not use this exact method again.

Recommendations: It would be best if the video could be recorded directly to DVD, mitigating the time taken changing tapes.

Webcam and laptop

- The filming method itself is much less intensive as webcam and laptop can be left running, recording for days.
- Relatively inexpensive (webcam $45, HandyAvi software $54).
- Image quality is much lower than film, but this would be improved through using a better quality webcam with a higher resolution.

- The angle of viewing was reduced due to the need to have the webcam placed close to the enclosure to ensure viewable image quality.
- Major downside in that the camera did not film in the dark (although it stated that it would) so a better night vision specific camera would be needed.
- The reviewing took an exceptionally long time because the movement of shadows caused by the trees in the wind meant that even with a low sensitivity setting, thousands of frames were recorded.
- Difficult to ascertain actual time of movements recorded, as recording is not constant, and the frame number is not shown in the video.
- The convenience of watching the film on the computer made this method much more efficient than the video, but the need to watch frame by frame to re-check movements was exhausting (took months).
- Would use this method again if could record with a webcam of a higher resolution that functioned at night, if it was set up to connect to a computer housed inside.

7.0 Recommendations for future projects

- Set up a video camera with an infra-red attachment for night vision, wired up to an indoor computer (similar to filming of Kea nests at Hamilton Zoo in 2009) for constant filming.
- Set up a wireless Red Eye camera by Mi5 security, which has a motion sensing function and a high quality infrared video for filming at night (costly, at $1345+).
- If using motion sensing, set up a clock in the enclosure to measure time more effectively.
- If using the Canon video camera, improve night time filming using an extra infra-red Canon light. Only use this method if recording to DVD or a computer.

- Camera/webcam should be suspended above the enclosures to maximise the probability of seeing frogs.
- Use a webcam with night vision and high resolution.
- Ideally, recording would occur simultaneously on the three cells, so that no emergence events were missed. This would be feasible using three webcams hooked up to three computers or three Redeye wireless cameras.

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