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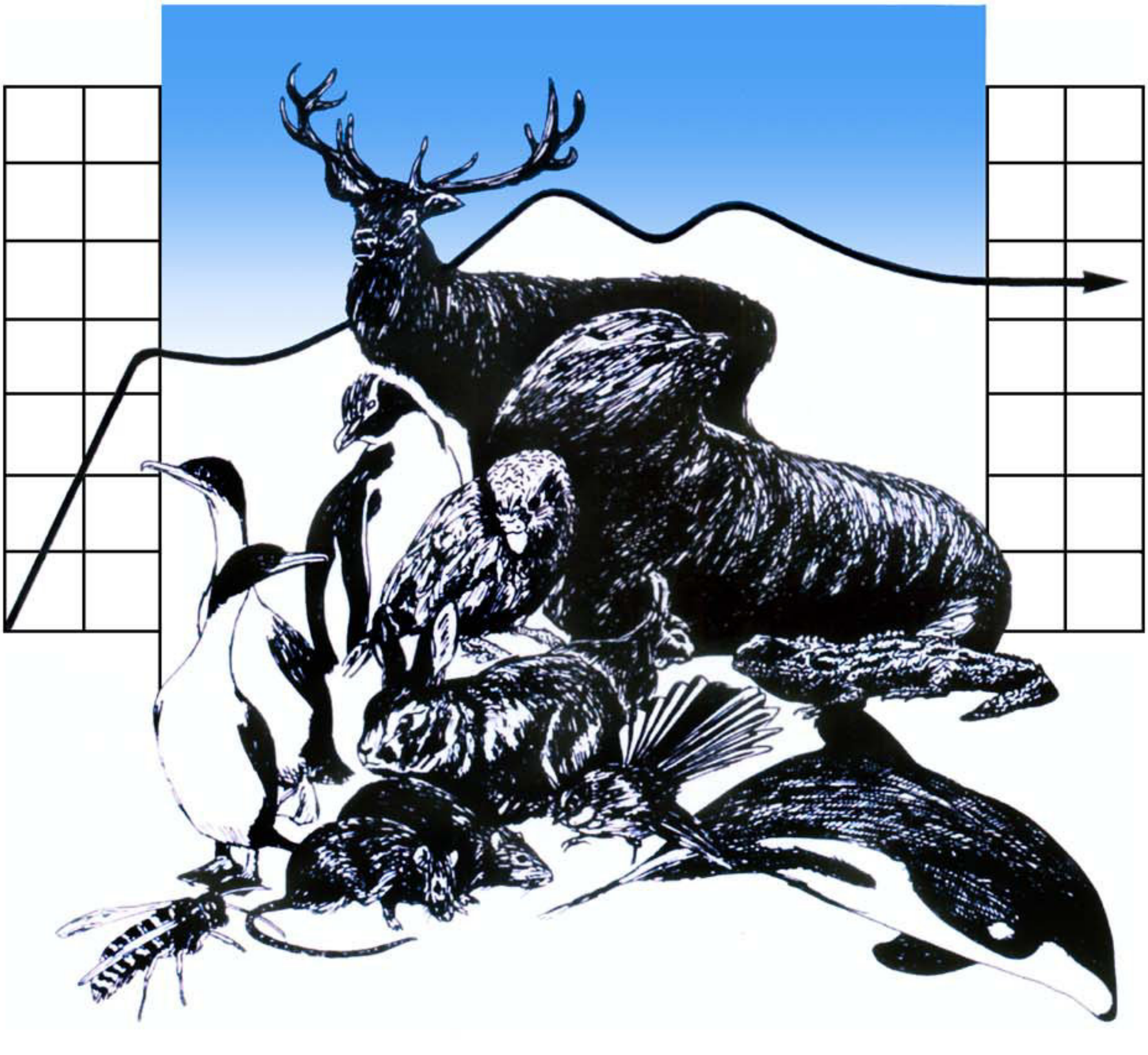

WILDLIFE MANAGEMENT

Trials and Evaluations of Monitoring Tools for New Zealand's Alpine Skinks: The Barrier skink (Oligosoma judgei) and the Sinbad skink (O. pikitanga)

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Trials and Evaluations of Monitoring Tools for New Zealand's Alpine Skinks: The Barrier skink (*Oligosoma judgei)* and the Sinbad skink (*O. pikitanga*)

Barrier skink (*Oligosoma judgei*), Cheviot Faces, Takitimu Mountains, Southland
(Photo: Luke Johnston)

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1. Executive Summary

New Zealand's only two skink species known to live exclusively in the alpine zone were discovered relatively recently. The Sinbad skink (Oligosoma pikitanga) was discovered in 2004 and the Barrier skink (O. judgei) in 2005. Since the discovery of these species, they have received limited attention and consequently, there is still very little known about either species. Both species are listed as Nationally Endangered and appear to have specific ecologies, with very limited distributions.

With little alpine skink work being attempted, it is important that the first step is developing feasible and robust tools for monitoring and researching skinks in the challenging alpine environment. This report aimed to evaluate the use of three different tools in alpine skink monitoring.

The first tool evaluated is the use of newly developed Kinopta Blackeye 2W camera traps. Cameras were deployed at known alpine skink sites (Cheviot Faces, Takitimu Mountains, Southland and Sinbad Gully, Llawrenny Peaks, Fiordland) for short periods and footage reviewed. The cameras had poor capture rates for both Barrier and Sinbad skinks so no meaningful analyses could be conducted. The use of the cameras in the field however, did allow the identification of a number of areas of improvement that are required for camera trapping to be a feasible option for alpine skink monitoring. It was concluded that primarily, if resolution and image quality are improved and adjustments are made to skink detection software, then camera traps remain a monitoring tool with great potential.

The second tool evaluated was photo-identification for Barrier skinks at Cheviot Faces. A number of Barrier skinks were captured and photographed at Cheviot Faces. Photographs were then reviewed and two photo libraries were created. Seven personnel with herpetological experience were then asked to match individuals from different photos using natural markings and scale patterns between the nose and forelimb. The high level of accuracy with which all participants were able to match individuals, indicates that photo-identification is likely to be an effective tool for

monitoring Barrier skinks. There were some inaccurate identifications by participants and it appears experience in skink photo identification of both the photographer and identifiers are key to accurate identifications. Further research is required assessing long-term stability of patterning and with a larger archive of photographs.

Thirdly, correlations of Sinbad skink detections with environmental variables at Sinbad Gully between 2012-2014 were analysed. These surveys involved constant human observing at a specific known skink site and recording skink sightings and weather conditions. The data collected from these surveys was analysed to model skink detection rates with relation to weather conditions. A best model was identified that predicted Sinbad skink detection is correlated with rock temperature, wind speed and significantly with humidity. These results can provide an initial guide for future survey efforts to maximize detection and minimise variation in observation rates. However there are a number of limiting factors such as a small sample size and the absence of potentially important covariates likely to be masking true relationships. Therefore results should be accepted tentatively and further investigation is recommended.

The opportunity is also taken in this report to record some collateral findings during fieldwork such as: an extension of the known distribution of Barrier skinks at Cheviot Faces, Takitimu Mountains, Southland; behaviours of Barrier skinks at Cheviot Faces; pest observations at Cheviot Faces; observed ectoparasite infection of Barrier skinks at Cheviot Faces; and the discovery of the presence of the Cascade gecko (Mokopirirakau "Cascades") at Cheviot Faces.

The findings of this report provide a positive step forward in the conservation of these important Oligosoma skinks and can be used to help guide future monitoring and research attempts. It is emphasized that a large amount of effort is required to further understand and to ensure the persistence of the Barrier and Sinbad skinks.

2. Introduction to New Zealand's alpine skinks

New Zealand is home to a rich diversity of skink species with a wide range of ecologies and behaviours. Research and discoveries continue to add new species to this known diversity every year. The alpine area of New Zealand remains relatively unexplored as far as herpetology is concerned and has the potential to be home to many unknown lizard species, particularly in Fiordland (Bell and Patterson 2008). New Zealand geckos such as the black-eyed gecko (Hoplodactylus kahutara) have long been known to live in the alpine zone (Whitaker 1984). However, the relatively recent discoveries of two new Oligosoma skink species in the alpine zone of Fiordland are proof that New Zealand skinks are also capable of living in some of our harshest environments.

In March 2004, during a survey for alpine geckos, the Sinbad skink, Oligosoma pikitanga was discovered. The Sinbad skink was found in the Sinbad Gully, Llawrenny Peaks, Fiordland (Bell and Patterson 2008). The skinks were on a north/northwest facing vertical cliff in the alpine cirque basin at the head of the Sinbad Valley at 1100m above sea level (ASL) (Bell and Patterson 2008). In February 2005, another skink species, the Barrier skink, Oligosoma judgei was discovered by climbers about 20km southeast of Sinbad Gully on Barrier Knob in the Darran Mountains, Fiordland at 1600m ASL (Patterson and Bell 2009). The Barrier skink was found on near vertical rock bluff habitat (Patterson and Bell 2009). It was initially believed that the Sinbad and Barrier skinks were of the same species however, further research determined they were separate species (Bell and Patterson 2008). Although the two skinks have a relatively small genetic distance (3%), they are easily distinguished by their morphology and behaviour (Bell and Patterson 2008).

Figure 1- a) A Sinbad skink (Oligosoma pikitanga) (Photo: James Reardon);
b) A Barrier skink (O. judgei) (Photo: Luke Johnston)

The Sinbad Gully remains the only known locality of the Sinbad skink. Conversely, the Barrier skink has been discovered at other locations. An unlabelled specimen collected on Students Peak, Darran Mountains by G. Choate in 1966 has been confirmed as a Barrier skink, although no effort has yet been made to confirm their continued existence at Students Peak (Patterson and Bell 2009). In 2009, another Barrier skink population was found on the largely stable scree slopes of Cheviot Faces, in the western Takitimu Ranges at 1200m ASL (Patterson and Bell 2009). Barrier Knob and Cheviot Faces are separated by 100km and this coupled with distinctly different geologies suggests that Barrier skinks could be present throughout many mountain ranges in the area (Patterson and Bell 2009). There have also been possible Barrier skink sightings elsewhere that are yet to be verified (J. Reardon, pers comm.). Barrier skinks are known to live sympatrically with common skinks (Oligosoma polychroma) and mahogany skinks (Oligosoma inconpicuum *"mahogany"*) at the Cheviot Faces site (Edmonds 2009). The Sinbad skink lives sympatrically also with the mahogany skink and with the Cascade gecko (Mokopirirakau "Cascades") (Bell et al. 2008).

Research and monitoring efforts have thus far been limited for both alpine species. Sinbad skink monitoring has consisted of an annual 2-4 day occupancy and minimum numbers survey since 2012 (James Reardon, pers comm.). Barrier skink monitoring has consisted of similar occupancy surveys, but less regularly (Bell et al. 2008; Edmonds 2009; Lettink 2010). Both skink species have a Nationally Endangered conservation status (Hitchmough 2013) despite our very limited knowledge. Barrier and Sinbad skinks are living in what is considered unusual and difficult environments for ectothermic animals. The mean annual temperature of the area is only 6.5°C and the mean minimum of the coldest month is -0.7°C (Leathwick et al. 2003). Sinbad and Barrier skinks living in these high altitude areas must survive exposure to rain bearing clouds, westerly winds and low sunshine hours, less than 1600 hours per annum (Atkinson and Merton 2006). Current knowledge suggests habitat prerequisites are north facing alpine areas with deep rock crevices or scree, for protection from snow and the elements. Population estimates are yet to be developed for either species and range, habitat, microhabitat, distribution and other ecological factors are yet to be explored. It cannot even be said with certainty that either species is strictly adapted specifically for alpine living with suggestions the skinks may have been pushed into these alpine zones, seeking refuge from introduced pests (Bell and Patterson 2008; J. Reardon pers comm.).

Alpine skinks no doubt offer fascinating ecologies and behavioural adaptations but at this stage we have a long way to go to uncover these adaptations as we know next to nothing about these species. Working in the alpine zone with such cryptic species offers a host of challenges, especially considering that populations are living on cliff faces. There is a large amount of dependence for access and detection of the lizards on weather which is constantly changing. Often only small windows of fine weather are available to allow fieldwork to occur. Extensive surveys require a level of climbing experience and gear. Fieldwork can realistically only be carried out during summer as habitat is snow bound otherwise. Funding is a major barrier, with limited funding currently allocated to these species. Access to sites is difficult. The alpine skink work is expensive as for a lot of the fieldwork, helicopters are required for access and transport of gear to the study sites. These are only some of the barriers that make research and monitoring of these alpine skinks so daunting. Therefore it is critical for the conservation of alpine lizards that the first steps be the development of efficient and effective research and monitoring methods.

Within this report, I aim to assess the potential of three different monitoring tools for alpine *Oligosoma* skinks. Firstly, I will evaluate the use of a new model of camera trap, Kinopta's Blackeye 2W camera. Second, I aim to determine whether individual Barrier skinks at Cheviot Faces can be identified based on natural markings for photo-resight analyses. Thirdly, I aim to analyse results from observer monitoring in relation to weather conditions from the annual Sinbad Gully skink surveys to determine relationships between weather variables and Sinbad skink detection to guide future survey efforts.

3. Evaluation of Kinopta Blackeye 2W cameras for alpine skink monitoring

3.1 Introduction

Alpine skink conservation is in desperate need of a tool that allows researchers to easily and economically obtain occupancy data and abundance estimates. There remains no abundance estimates for either Barrier or Sinbad skinks and occupancy data to date is limited to a 2-4 day annual monitoring period for Sinbad skinks only (J. Reardon pers comm.). Patterson and Bell (2009) did provide a tentative density estimate of 5-8 Barrier skinks per 50x50m area on Barrier knob however, this was a crude estimate that was uncorrected for habitat bias and didn't account for detection probabilities. Detection probabilities are important to obtaining robust estimates of density and occupancy for cryptic *Oligosoma* species (Seddon et al. 2011). Environmental conditions have a significant impact on likelihoods of observing skinks and therefore any tool used for monitoring alpine skinks must be able to include and account for these variables.

Camera traps coupled with the monitoring of weather variables are a potential answer to a number of issues posed by alpine skink monitoring and could importantly guide the conservation efforts required for alpine skinks. Camera trapping is a tool that is becoming more widely used in conservation thanks to improvements in technology and the development of analytical techniques (O'Brien 2011). It is a tool that has been used in a range of species from jaguars, *Panthera onca*

(Quiroga et al. 2013) to wombats, Vombatus ursinus (Borchard and Wright 2010) to komodo dragons, Varanus komodoensis (Ariefiandy et al. 2013). Camera trapping offers the major advantages of constant monitoring, reduced time and effort investment and is a largely non-invasive tool (O'Brien 2011).

Camera traps can be split up into two main categories: triggered and non-triggered (Swann et al. 2011). Triggered traps take photographs when an animal sets a camera trap off either through a mechanical trigger or a sensor such as infrared (Swann et al. 2011). Non-triggered traps are traps that continuously take photographs at a programmed rate (Swann et al. 2011). Triggered traps have the advantage of only providing photos of interest and allow faster analysis. Unfortunately, triggered traps commonly have issues where animals may be missed as the animal moves out of focus before the camera is triggered (Swann et al. 2011). Sometimes an animal may also fail to trigger a trap, a point for Barrier skinks where as ectotherms, infrared will provide limited success. With triggered traps, you cannot be certain that photographs of animals have been taken every time an animal has passed by (Swann et al. 2011).

Non-triggered traps however are known to fail far less frequently and have the advantage of continuous photography so that presence/absence can be robustly determined (Swann et al. 2011). There are some disadvantages though, in that a large amount of storage space is required and powering the cameras can be an issue when left running for extended periods. Also, analysis of photographs can be time consuming for downloading and a researcher must go through an excessive number of photographs to find which are of use and contain animals (Swann et al. 2011).

A camera and software has recently been developed by New Zealand company Kinopta (http://www.kinopta.com/), which may counteract a number of these issues. The Kinopta Blackeye 2W camera is capable of taking between 2 and 5 frames per second (D. Peat, pers. comm.). The camera is waterproof, has a moderate amount of internal storage space, up to 128GB (D. Peat, pers. comm.) and can be connected to any 5V, 12V or solar power source which is beneficial when dealing with difficult to access locations such as those of alpine skinks. All photos can then be downloaded from the camera via Wi-Fi to any Wi-Fi capable device. Potentially the most useful feature is the software that accompanies the Blackeye cameras. The software is capable of filtering through all photos and providing the user with only those photos with novel entries, saving a large amount of time investment (D. Peat, pers. comm.). It is unknown if the cameras will be effective enough and have the resolution to identify individual lizards which is required for accurate abundance estimates, however they should at least be of use for presence/absence and minimum numbers monitoring for abundance indices. If Kinopta Blackeye 2W cameras are suitable for alpine skink monitoring, it will open up the ability to deploy cameras with a power source at a given site for an extended period, along with a weather station. Then the cameras and data can be collected at a later date providing large quantities of more representative information whilst requiring little field effort and with a reduced reliance on fine weather windows.

Camera traps have become a common wildlife monitoring tool despite equipment often not being suitable and with little background research (Meek and Pittet 2013). Therefore it is important that studies are undertaken to assess suitability of a camera trap for a specific research interest before committing to results provided by camera traps. With this study, one aim is to evaluate if Kinopta Blackeye 2W cameras capture skink movements as effectively as human observations and if the software is capable of accurately identifying alpine skinks as a novelty. This study aims to model skink sightings by Blackeye 2W cameras with environmental data to obtain detection probabilities and to gain knowledge about alpine skink movements in relation to abiotic factors. It is also aimed to determine whether alpine skink colour and scale patterns can be easily observed in images captured by Blackeye 2W cameras.

3.2 Methods

3.2.1 Cheviot Faces

Two locations were selected to trial Kinopta Blackeye 2W cameras for alpine skink monitoring. The first location was known Barrier skink habitat at Cheviot Faces, Takitimu Mountain Range, Southland from 24 to 28 January 2014. A fine weather window was forecast for this period. The first day was spent with two people surveying the scree slope by slowly walking up and down the slope at a distance of about 15m from each other. Surveyors scanned for basking and moving Barrier skinks. Particular attention was given to pockets of deep scree as this is where they have been commonly seen (H. Edmonds pers comm.). GPS coordinates were recorded at points where Barrier skinks were sighted and it was noted if multiple Barrier skinks were observed at a site.

At the end of day 1, two sites were selected at which to set up the Blackeye 2W cameras. Sites were selected based on where multiple Barrier skinks had been observed, therefore making capture of skinks on camera likely. It was ensured the selected sites were at a distance of greater than 100m apart to make any captures on cameras likely to be independent, although it must be noted this is based on known movements of Otago skinks (Germano 2007) and not Barrier skinks. An Aercus WS2083 weather station was also set up at Cheviot Face to allow models to later be created which included weather variables. Weather variables were logged every 30 minutes and included air temperature, relative humidity, wind speed, wind direction and barometric pressure.

One camera was set up at ~1240m ASL on a tripod while camera 2 was set up at ~1300m ASL on a stacked rock cairn. Camera views were positioned using a laptop computer to ensure camera focus was at the desired point. Cameras were set up at a distance 2.5-3m from the focal point. The frame of view was marked on the scree so that observers could determine if skinks were within the cameras frame of view or not. Cameras were set up to run in the “normal” mode at 2 photos per second (fps).

Figure 2 – Example of camera set up at Cheviot Faces, Takitimu Mountains, Southland (Photo: Emmanuel Oyston).

On day 2, from 9am-5pm each camera site was monitored for 15 minutes every hour. Observers recorded the time that skinks were seen and whether or not sightings were within the frame of view or not. This was to facilitate comparisons in the ability of a human observer to sight skinks with the ability of the Blackeye 2W cameras. At the end of day 2 cameras were turned off and collected as bad weather was forecast. Day 5 brought a suitably fine day so cameras were set up at the same sites as day 2 for the duration of the day and the same monitoring protocol was followed.

3.2.2 Sinbad Gully

The second location selected for trialing the Blackeye 2W cameras was Sinbad Gully on 4-5 March. A field team of four went into Sinbad Gully as a fine weather window was forecast. Two sites were again selected to deploy the cameras at. The first site was in a small rock pile where a Sinbad skink had been observed the previous season (James Reardon pers comm.). This site was of particular interest as Sinbad skinks had not previously been seen at such a distance from the cliff faces. The second site was focused on a section of the north facing cliff face in Sinbad Gully where multiple Sinbad skinks have been sighted on previous trips and where annual occupancy and minimum number surveys have been focused for several years.

Both cameras were set up on tripods and frames of view positioned using laptop computers to obtain the desired shot. Cameras were set up at ~10:30am on the morning of day 1 and were left running continuously in "normal" mode at 2fps until approximately 4pm on day 2. The site of camera 1 was not formally observed while the standard annual occupancy monitoring survey was carried out at the site of camera 2. This survey involved continuous monitoring by a human observer between the hours of 10:30am and 4pm. Every 15 minutes the observer would record the number of skinks seen, number of sunshine minutes, rock temperature and obtain air temperature, relative humidity, wind speed and barometric pressure for that period from a hand held Kestrel device. At the end of day 2, cameras were turned off and collected.

Camera footage from both locations was then reviewed in office using the Kinopta software built into the cameras. Reviewing footage involved going through all photos which the Kinopta software identified as having a novelty and then going through every single photo to ensure the software was missing any skink sightings. If a skink was sighted then the time when the skink first appears in view and the time when it leaves view was recorded.

3.3 Results

Detection levels of the skinks by the cameras were too low for accurate occupancy estimates and detection probabilities. At Cheviot Faces no skinks were observed during the 15 minute monitoring periods at either of the camera sites on any of the days. Camera 1 at Cheviot Faces only made 2 sightings of skinks throughout the time it was deployed while camera 2 only made 3 brief sightings. All sightings by both cameras were on day 2. Camera 1 did however capture some notable social behaviour in one of the sightings where one Barrier skink follows another out from underneath a rock, they then sit and bask on a rock for about a 2 minute period, one lying on top of the other before one moves away and the other one follows.

At Sinbad Gully, no skinks were captured on either days by camera 1 at the lower rock pile site. Camera 2 did not capture any skink sightings on day 1. On day 2, there were several skink sightings however, only one could be identified with certainty to be a Sinbad skink. The other skink sightings appear likely to be mahogany skinks. No pests were captured in any camera footage.

These results determined that no meaningful comparisons of human observer versus camera traps could be made nor could any detection probabilities be calculated.

3.4 Discussion

Due to weather and other logistical issues, research was limited to only two short field trials and this coupled with poor capture rates on the cameras did not allow any significant analyses to be conducted. The fact that trials were over such a short period means camera trapping cannot be determined as being viable or not for alpine skinks at this point. However, the short time that was spent using the Blackeye 2W cameras in the field and the associated software, proved invaluable for identifying weaknesses and areas of potential development if camera traps are to be used for alpine skink monitoring.

3.4.1 Image quality

One of the biggest issues with the Blackeye 2W cameras was the quality of images the cameras capture. The Blackeye 2W is a VGA camera with resolution that makes it very difficult to distinguish species characteristics let alone markings of individuals from a practical distance. Skinks would need to be within about 40cm of the camera for the images to show markings of skinks with clarity. The cameras need to be set up at a greater distance than this in order to capture a sizeable frame of view to increase the likelihood of encountering skinks. Identification of species is crucial in alpine skink monitoring and the use of scale pattern and colouration is a simple method of doing so, but the use of markings on individual Barrier and Sinbad skinks could also be advantageous to alpine skink monitoring. Therefore, a camera with greater resolution is required if camera traps are to be used. A higher resolution wildlife camera is more than within technological limits as many small handheld cameras can now easily take images of 1080p quality or 8MB images. Also, the cameras used captured black and white images. With the use of colour images, pattern recognition of species and individuals would be easier. The Blackeye 2W may meet resolution requirements for the monitoring of larger wildlife such as detecting the presence of possums or cats but not for identifying alpine skinks.

Another improvement to increase image quality would be to have cameras with interchangeable and focusable lenses. It is possible to change lenses in the Blackeye 2W cameras but a level of skill is required. Sites in which both Barrier and Sinbad skinks occupy are highly variable in size, shape and slope. Different sites require cameras to be positioned differently, therefore the ability to adjust frames of view and to focus images to suit individual sites would mean improved images could be captured.

3.4.2 Kinopta software

The process of reviewing footage through the built-in Kinopta software uncovered another problem. One of the major advantages of Kinoptas software is the function which identifies images with novelites and theoretically should filter out thousands of images with nothing of interest and present the reviewer with only images where an animal such as a skink is present. The software has potential to save the reviewer a large amount of time, particularly if cameras were to be left running taking 2fps for an extended period. However, of the >850,000 photos taken during the field trials, the software still identified >460,000 photos as having novelties despite <1000 having skinks present in the images. This meant a large amount of time was still required by the reviewer to filter through images. The alpine habitat is often windy and the vegetation consists of mostly shrubs and tussocks. Due to the relatively small size of skinks, settings for the size of novelty that the software must filter from the captured photographs must be at the lowest point. This meant any movement of vegetation caused by wind was also identified, rendering the software largely redundant. When setting the cameras up at chosen sites, the best attempts were made to exclude vegetation from the frame of view but it is nearly impossible to completely exclude vegetation from being captured in the frame. It becomes a trade off in the size of the frame of view (as was discussed previously, needs to be as large as possible) with the amount of vegetation included in the image.

A solution may be to develop a function that allows cropping of multiple, polygon shaped areas in the frame of view that are not to be scanned by the software for a novelty. The Kinopta software currently has a cropping function that allows the user to draw a rectangle for the area in the image the user wants the software to scan however, the rectangle shape means a large amount of non-vegetated area where skinks could move is also excluded from being detected. A multiple polygon cropping function would allow the user to crop tightly around any vegetation in the image whilst still including all other areas to have novelties identified. Then the software may be more effective in presenting the reviewer with only skink sightings and less noise, saving a large amount of time. Another function that could be added to the software to improve efficiency is the option to download all and only images with novelties. Currently the user is required to manually select the desired regions of memory with images with novelties which is time consuming if there are many skink sightings spread out through the memory. A function that automatically downloads all images with novelties would be advantageous.

It must also be noted that although skinks were not present in any photographs where no novelty was detected, images are given a score based on the size of the detected novelty and many photographs with skinks present had very low scores. This indicates the software is only just sensing the skink movements or potentially not at all, as the small score may only be vegetation movement. Trials in a controlled enclosure where skinks are the only possible source of movement are advised to determine if software sensitivity is at the required threshold as it may need to be enhanced for use in alpine skink monitoring.

3.4.3 Image storage

An important improvement required for the Blackeye 2W cameras for alpine skink monitoring is an external image storage system such as a compact flash (CF) or a solid-state drive (SSD). The current Blackeye 2W cameras have internal image storage and to obtain images, they must be downloaded either via Wi-Fi or USB. Images must also be downloaded or deleted to free space on the camera so that it can continue to run. Downloading a few days images to a laptop computer or similar device can take several hours and is not practical in the field. Removable storage would be far more beneficial for alpine skink monitoring as CFs and/or SSDs could simply be swapped over in the field so cameras can continue to run without being limited by storage space while images already captured can be taken out from the field and analysed. An additional feature of the use of SSDs for example, is that they are available with storage capacities of up to 640GB, far exceeding the highest internal storage capacity of Blackeye cameras, which are capable of holding up to 128GB.

3.4.4 Additional points

Further points are that the Blackeye cameras presented no issue with weather proofing however were not in the field for extensive periods nor subjected to some of the harsher conditions that are common in the alpine zone. Further trialing is recommended to determine the durability of cameras. Another point is the Blackeye cameras have a standard tripod attachment and a tripod was the best method of attachment to set the cameras up. Alpine skink sites are on slopes and faces of varying gradients and require a stable attachment to keep the cameras steady. Tripods with adjustable legs and that can be weighted down worked effectively. Other methods of attachment may need to be considered though if sites higher on the cliff face at Sinbad Gully are to be monitored by camera traps as there may not be suitable platforms to stand tripods on. More permanent camera housings attached to the cliff face could be considered. Also, the Wi-Fi feature of the Blackeye 2W cameras may not be suitable for downloading of images but it did prove a useful feature for determining what area the camera was photographing (frame of view) during the initial set up. The cameras could be set up easily by viewing a clear image on a tablet or laptop computer in the field. The use of Wi-Fi transmission to a portable Wi-Fi device was also valuable for checking cameras were still running correctly during trials.

A positive outcome of the trial monitoring was that although very few skink sightings were made by the cameras, some skinks were captured in footage. No skinks were seen however, during observer monitoring periods and this demonstrates the advantage of continuous monitoring. With continuous monitoring, skinks will be observed that otherwise may not have been. Continuous monitoring using cameras allows areas to be monitored in all weather conditions, at all times of the day and means a more complete understanding of alpine skink behaviour and the influences of weather, can be developed. Continuous monitoring with cameras can provide a guide for when and under which conditions time could be best spent surveying new areas of habitat where alpine skink presence is unknown. Or, camera-traps could be used themselves to monitor potential habitat to give a more robust determination of presence-absence.

3.4.5 Conclusion

Overall, Kinopta's Blackeye 2W cameras and software in the current design are not a viable option for alpine skink monitoring. The discussed issues need to be addressed, particularly the resolution needs to be improved, the frame of view needs to be increased and cameras need to be run for extended periods. Continuous monitoring with the use of camera traps remains a potentially valuable tool for alpine skink monitoring and further investigation is justified.

4. The viability of photo-identification for the Barrier skink (Oligosoma judgei)

4.1 Introduction

The identification of individuals in a population is important for research into population size and viability, life-spans, reproductive outputs and individual movements (Hitchmough et al. 2012). Photo-identification (photo-ID) is a method in which individual animals are identified from their natural markings (Speed et al. 2007). Photo-ID has been successfully used in the research of a wide variety of animals such as whales (Auger-Methe and Whitehead 2006), badgers (Dixon 2003), cheetahs (Kelly 2001) and salamanders (Gamble et al. 2008). It is also a well established technique in herpetology and has been successfully used for a number of New Zealand's Oligosoma skinks including the Chevron skink (O. homalonotum; Barr 2009), the small-scaled skink (O. microlepis; Gebauer 2009), and the grand (O. grande) and Otago skinks (O. otagense; Reardon et al. 2012). High resolution, standardised photos of a region with suitable variation are taken of individuals. The nose-forelimb region has proven effective for identifying individuals in a number of Oligosoma species (Gebauer 2009; Reardon et al. 2012). Photographs of individuals are taken in an initial survey of a population and a library of individuals developed. In following surveys photographs are again taken and can be determined as being either recaptures or new captures depending on a match being present in the library. This method can then be used in a number of different mark-recapture analyses to analyse abundance, survival, reproductive rates and home ranges. Photo-ID has been a successful method in monitoring populations and responses to management for grand and Otago skinks in the Macraes Flat conservation project (Reardon et al. 2012), providing data to obtain outputs from the MARK program (White and Burnham 1999). If photo-ID is possible for Barrier skinks, it could prove a valuable tool for understanding population parameters and gaining estimates to more accurately guide allocation of their conservation status.

Photo-identification is a more attractive option than other permanent marking methods such as toe clipping, as photo-identification is less invasive. Photo-ID. provides a cheap and long-term alternative without causing stress to the animals (Saachi et al. 2010). Handling of skinks can impact their behaviour (Germano 2007) and toe coding is more susceptible to error as natural toe loss occurs (Saachi et al. 2006). Both factors can reduce the accuracy and precision of a study. Photo-ID also makes cultural opposition to toe clipping a redundant issue. However, photo-ID is not without its disadvantages. The sensitivity of photo-matching is subject to a level of observer error and may not always be 100% accurate. It can also be very time-consuming to match recapture photographs, making the process particularly difficult when there is a large photo archive. These issues are being addressed through the development of pattern recognition software (Bolger et al. 2012; Gamble 2008; Saachi et al. 2010). This software will improve efficiency and allow monitoring of larger lizard populations (Bolger et al. 2012; Gamble 2008; Saachi et al. 2010). The software is currently being developed for the Macraes Flat, grand and Otago skink programme (James Reardon pers comm.) so may become an option for Barrier skinks should a large photo archive be developed.

A pilot study is important when considering photo-identification as a tool for population analyses as suitability must be determined for specific species. It must be confirmed that features are adequately variable to distinguish individuals that observers can accurately identify recaptures and that selected regions of the skink (nose to forelimb) are suitable (Kenyon et al. 2009). Therefore, it is aimed in this study to trial the effectiveness of photo-identification of individuals for Barrier skinks (O. judgei).

4.2 Methods

Surveyors spent one day with suitable, fine, sunny weather scanning known Barrier skink scree habitat at Cheviot Face, Takitimu Mountains, Southland. If a Barrier skink was sighted, surveyors would attempt to capture the skink. If captured, both lateral sides of skinks were photographed with preference for the nose to forelimb region to become a part of a photographic library. Photographs were then taken again focusing on the nose to forelimb region, but at a greater distance to simulate a "wild" photo as would be expected without capture. Whenever possible, photographs were also taken after release to use as "wild" recapture photos. As many skinks as possible were caught and photographed over the period of the day.

Photographs were then screened, removing images which were not in focus or where head angles were not suitable. The best images of the left and right sides were coded and archived to form a small photographic library. Suitable left and right photos were archived for 10 individual Barrier skinks. A "wild" photo was then selected which matched 8 of the archived skinks. These wild photos were assorted in random order with two "wild" photos of skinks not archived also being mixed in. These photos were then presented along with the photo library to seven biologists with a level of herpetological experience. The biologists were given 30 minutes and were asked to attempt to match "wild" photos to a respective archived photo as accurately as possible based on markings of the skinks between the nose and forelimb. The period of time allowed for considered matching and sorting of images. The accuracy of matchings was recorded as the percentage of "wild" photos correctly matched to the archived individuals.

Figure 3 – An example of the photographs used for the "capture" photo library with the box showing the nose to forelimb area focused on for matching individuals (Photo: Emmanuel Oyston).

Figure 4 - An example of the photographs used for the “wild” photo library (Photo: Luke Johnston).

4.3 Results

Of the seven participants who trialed the photo-identification study, two participants matched individual Barrier skinks with 100% accuracy while the other five participants each matched individual Barrier skinks with 90% accuracy, incorrectly identifying one individual each.

Table 1. Results from photo-identification trial for Barrier skinks

Number of Participants	Mean Score	Standard error
7	92.86%	0.018

Of the five incorrect identifications, only one was a misidentification, where a “wild” skink was wrongly identified as being another individual from the “captured” photographs. The other four incorrect identifications were all non-identifications where a “wild” skink was incorrectly stated as having no match in the “captured” archive when it did in fact have a match in the “captured” archive. Of the five incorrect identifications, two skinks were incorrectly identified twice and one skink was incorrectly identified once.

4.4 Discussion

With the use of photo-identification and a standardised sampling method, robust estimates of demographic parameters can be obtained (Knox et al. 2012; Reardon et al. 2012). The results of this trial indicate that photo-ID is likely to be a viable monitoring tool for Barrier skinks, however there are issues that require addressing. Participants expressed that the nose-forelimb profile was a suitable region to focus on as the eye, ear and forelimb provided reference points for distinguishing features. The nose-forelimb region also included the strong gold/green stripe along the top of each flank characteristic of Barrier skinks. Participants concluded this stripe commonly had unique, distinctive patterns useful for identifying individuals.

There were participants who identified individuals with 100% accuracy proving the sample of Barrier skinks produced in this study could be accurately identified. The presence of inaccuracies by some participants has a number of possible explanations. Whilst screening and selecting photographs to be used to create the "captured" and "wild" archives, a large proportion of photographs were not suitable due to either lack of focus or poor profiling of the nose-forelimb region. The photographs that were selected were the best available, however many were still not ideal as the skinks often had their necks curved, partially obscuring some patterning. The low quality of some photos presented in the trial made examination some individuals difficult and may be attributable to some inaccurate identifications. The low quality photographs are due to inexperienced observers taking the photographs. Photography of skink patterning for identification is a skill that requires practice (Gebauer 2009; Reardon et al. 2012). Image quality would likely improve as observers became more experienced in photographing Barrier skinks and developed an understanding for optimal skink positioning and camera settings for photo-ID (Gebauer 2009; Reardon et al. 2012).

Inexperience of participants in the trial is also likely to be a factor in inaccurate identifications. Knox et al. (2012) highlighted the intuitive issue that experience in photo-ID of skinks can impact a participant's photo-identification abilities. Participants all had an understanding of photo-identification methodology and had some experience working with Oligosoma skinks. However, only one participant had extensive skink photo-ID experience having worked with grand and Otago skinks and no participants had ever seen or examined Barrier skink patterning. Participants commented that even as they progressed through the short trial, identification became easier as they developed a perception for distinguishing features of Barrier skinks and a technique for examining individuals. Participant inexperience likely contributed to the observed inaccurate identifications. Despite the inexperience, the mean accuracy percentage was still above 90% suggesting identification for Barrier skinks does not require a high level of expertise.

It is important to emphasise that only one inaccurate identification was a misidentification while all other inaccuracies were non-identifications. Misidentifications are more detrimental to the use of photo-ID for abundance estimates as they indicate high similarity and a low level of variation between individuals in the population, so error rates will be high (Friday et al. 2000). Conversely, non-identifications are more likely due to either an individual skink with a lack of distinguishing features or simply poor photographs where distinguishing features are obscured. Bias created by a small proportion of skinks that have poor distinguishing features can be accounted for in abundance estimates. However, inaccuracies were not always the same skink and some participants did achieve 100%. This suggests the presence of both misidentification and non-identification within this trial appear to be a product of the aforementioned inexperience of participants and low image quality as opposed to issues with variation and distinguishing features.

Overall, pattern variation between individual Barrier skinks at Cheviot Faces appears to be substantial enough for photo-ID purposes. Essentially though, this study trialed a relatively small sample size compared to what a photo-resight study would require. The small sample in this study may not be representative of the population. If photo-ID is to be used for Barrier skinks, it is important that error rates are determined with a larger archive to ensure variation between individuals in the population is adequate. It must be considered though that manual identification is best suited to when sample sizes are small (Gill 1978). The time taken to identify individuals may also be a factor requiring attention if larger archives are to be used. If identification takes too long for Barrier skinks, photo-ID could be rendered ineffective for large archives. Although, there are solutions to speeding the photo-ID process up such as categorisation (Auger-Methe and Whitehead 2006; Gill 1978). For example, it was observed that Barrier skink spots and lines vary along a gold to green spectrum and could be categorised based on their colour. Another solution is the rise of photo recognition software that can match photographs much more efficiently (Ravela et al. 2013). Photo recognition software, however, requires a large amount of species specific development and can be less accurate than manual matching, so would require trials also (Gamble et al. 2008).

Before photo-ID can be reliably used for Barrier skinks, it is important to consider long-term pattern stability (Reardon et al. 2012). For example, the spots of adult California tiger salamanders (Ambystoma californiense) are known to change over time (Reaser 1995). Pattern instability could lead to inaccurate recapture identifications where recaptured individuals are identified as being captured for the first time and hence create obvious biases for population estimates. Long-term changes in scale patterns have been monitored in the closely related grand and Otago skinks and changes have been observed, however at a negligible rate that does not significantly impact population estimates (Reardon et al. 2012). Pattern instability is unlikely to be an issue for Barrier skinks but must be accounted for if photo-ID is used in long-term studies.

Photo-identification can be an effective alternative to more intrusive methods (Knox et al. 2012). Photo-ID prevents repeated handling which is known to affect skink behaviour (Germano 2007). This study did involve initially capturing and handling Barrier skinks to ensure both left and right profiles of each individual were photographed. Having both sides photographed for the “captured” archive is important as patterns of Barrier skinks are asymmetrical. Barrier skinks could easily be caught by hand at Cheviot Faces making it an easy option for the purpose of this study to ensure both sides are photographed. However, it would be possible to photograph both sides of Barrier skinks without physically capturing them as they are avid baskers and appeared relatively unperturbed from a distance of >4m. Photographs of both sides of skinks without capture was achieved but was less reliable than simply capturing skinks as the observer could not always get viable photos of both sides. Another option would be to only use photographs of one side for photo-ID purposes, however this again may lead to some resights being omitted if the correct side cannot be photographed. If photo-ID is to be used for Barrier skinks then methods should be established from the beginning in respect to whether both sides will be photographed and if the initial “captured” archive will require physical capture or not. Despite the stress caused by photo-ID being likely to be minimal, it should still be factored when estimating population parameters (Willson et al. 2011).

Although indications are that photo-ID is a viable method for the Cheviot Faces population of Barrier skinks, one must be cautious in assuming viability at a species level. For example, photo-ID is recognised as a feasible tool for Jewelled geckos (Naultinus gemmeus) on the Otago Peninsula, however photo-ID is less accurate for populations of the same species on Codfish Island (Knox et al. 2012). There is potential that the Barrier Knob population of Barrier skinks may have less variation in patterning between individuals, reducing feasibility of photo-ID as a tool at Barrier Knob. Reduced variation in patterning is particularly possible for such a population that has likely undergone bottlenecking in recent times due to the introduction of mammalian pests. Therefore if photo-ID is to be used at Barrier Knob, an independent trial of the population is required to confirm viability.

This study has indicated that individual Barrier skinks from the Cheviot Faces locality can be accurately identified by examining scale patterning in photographs of the nose-forelimb region.

However, to ensure high accuracy, a level of experience in photo-identification of skinks is advised for both the observer photographing individuals and for observers matching individuals. Observers should also gain familiarity with the patterning of the species before partaking in photo-identification monitoring. Further research should address long-term pattern stability and a larger photo library should be evaluated. Standardised photo-capture methods should also be established if any extensive research is pursued. Photo-identification is a promising and likely viable tool for Barrier skink conservation at Cheviot Faces, Southland and should be considered for monitoring of alpine skinks elsewhere.

5. Correlates of Sinbad Skink (Oligosoma pikitanga) emergence

5.1 Introduction

A suitable method for indexing or estimating absolute abundance of alpine skinks is critical to conservation management of the Barrier skink (Oligosma judgei) and the Sinbad skink (O. pikitanga). Population estimates are important not only for allocating species the correct conservation status but also for tracking changes over time and for measuring responses to management (Gu and Swihart 2004). Although efforts are increasing, there remains a lack of reliable techniques for monitoring cryptic species (Hare et al. 2007; Lettink 2007; Lettink and Cree 2007). Due to limited resources in conservation biology, methods that can be efficiently, practically and cost-effectively accomplished are essential (Roughton and Seddon 2006). Estimating absolute abundance is often not a viable option and using indices and methods such as site occupancy have proven to be successful for other New Zealand Oligosoma skinks (Roughton and Seddon 2006).

One of the greatest confounding factors in the use of indices and basic count data in conservation biology is incomplete detectability. For a longstanding period, abundance estimates and indices have often been assumed to have constant detection probabilities of 1 (MacKenzie et al. 2002; Schmidt 2003). This is despite very few species demonstrating complete detectability. Estimates that do not adjust for incomplete detectability are not reliable (MacKenzie et al. 2002; Schmidt 2003). Not accounting for detection probabilities can lead to abundances being both overestimated and underestimated and this can have serious implications, leading to misguided conservation management (Gu and Swihart 2004).

Reptiles can be particularly difficult to detect (Mazerolle et al. 2007) and New Zealand's Oligosoma skinks are no exception. Despite having adapted to tolerate colder temperatures (Cree 1994), the ectothermic physiology of New Zealand's Oligosoma skinks means activity levels show strong associations with weather variables (Coddington and Cree 1997; Lettink et al. 2011).

Oligosoma skinks are rarely observed active at low temperatures and are most commonly observed in warm, dry and sunny conditions (Werner and Whitaker 1978; Coddington and Cree 1997; Hare et al. 2009). These weather associations coupled with the cryptic behaviour of many Oligosma species creates a distinct heterogeneity in detection probabilities.

Population estimates and models that incorporate detection probabilities are becoming more common (MacKenzie et al. 2002) and it is important this trend continues for Oligosoma species. Roughton and Seddon (2006) successfully developed robust estimates of site occupancy for the endangered Otago skink (O. otagense) that accounted for incomplete detectability. The importance of accounting for incomplete detection was highlighted in a study of grand skinks (O. grande), where site occupancy estimates differed significantly when incomplete detectability was accounted for compared with when it was not (Seddon et al. 2011). Also, a Hoare et al. (2009) study demonstrated how monitoring protocols can be optimised, using correlations of weather variables with common skink (O. polychroma) detections to identify when best to survey artificial retreats to obtain robust population indices.

Understanding how variables influence alpine skink detection is crucial to precisely and accurately allocate resources for management. Ambient temperature, relative humidity, rock temperature, wind speed and time of day are some of the variables known to influence Oligosoma skink detections (Coddington and Cree 1997; Hoare et al. 2009; Roughton and Seddon 2006). However, it is likely that skinks in different climates will demonstrate different patterns of habitat use (Lettink 2007; Lettink and Cree 2007; Thiery et al. 2009). Therefore, skinks such as the Barrier and Sinbad skinks that live in the very demanding alpine zone, will likely respond to weather variables differently to those species at lower altitudes.

Data collection efforts to date are insufficient to estimate robust detection probabilities for alpine skinks. However, data has been collected during short annual surveys of Sinbad skinks in

Sinbad Gully, Llawrenny Peaks, Fiordland between 2012-2014. This data may be sufficient to analyse and make some initial positive steps towards identifying and understanding the correlation of some environmental variables with Sinbad skink detection. The aim of this study is to develop a model that correlates environmental variables with the observation rates of Sinbad skinks. Developing such a model may provide indications as to which variables are related and how those variables may be related to Sinbad skink detections. This information will not only improve our understanding of Sinbad skink biology but could also be used to guide future surveys.

Knowledge of which environmental conditions are optimal for maximum detection would allow survey efforts to be concentrated to conditions when higher emergence rates occur, standardising methods and reducing the major confounding factor of detection probability (Coddington and Cree 1997; Mazerolle et al. 2007). Correlations identified by this study will not allow inferences about causation; however it will highlight potentially important variables in Sinbad skink detection, providing a basis for the development of robust detection probabilities and consequently robust population estimates/indices.

5.2 Methods

5.2.1 Field surveys

Previous surveys of the north facing cliff face at Sinbad Gully led to a site being identified as suitable for annual occupancy and minimum numbers monitoring of Sinbad skinks. The site was selected based on multiple Sinbad skinks being observed there and the relative ease that the site can be reached, being only a small 5m high climb up to a ledge at the base of the cliff face. The monitoring involved a human observer continuously scanning the site between hours when the sun was shining on the selected site: 10:30am to 4pm. Every 15 minutes the observer would record the number of skinks observed, number of sunshine minutes, rock temperature and obtain air temperature, relative humidity, wind speed and barometric pressure for that period from a hand held Kestrel weather meter.

5.2.2 Statistical analysis

Data from surveys in 2012-2014 was included in this analysis. For each year, a minimum number of Sinbad skinks in the survey area was determined based on the maximum number of individuals observed at one time, each year. It was assumed that no Sinbad skinks left the population throughout the survey period within each year. Numbers of Sinbad skinks observed within each 15 minute period were then calculated as a proportion of the maximum number of individuals observed at one time. Data from each year was then plotted and compared visually. No yearly trends were evident so data was collated from the 3 years and analysed. All analyses were completed using R statistical software (R Core Team 2013). As data was based on comparisons of environmental variables with proportions of skinks observed which is not normally distributed, it was decided general linear models would be used (GLMs). Lattice graphs were used to investigate linearity of potential correlations between weather variables and skink observation rates to inform the types of models to use and to identify any strong correlations between weather variables. Variables included as factors in creating models were: shade air temperature, rock temperature, barometric pressure, wind speed, relative humidity, sunshine minutes and time of day. There was no over-dispersion so a binomial rather than quasibinomial object was considered adequate for GLMs. All possible models were compared using Akaike's Information Criterion (AIC; Burnham and Anderson 2002) and summary statistics are presented for the full model and the best model.

5.3 Results

There were 72, 15 minute observation periods in 2012 with a maximum of four individual Sinbad skinks observed at one time. In 2013, there 29, 15 minute observation periods with a maximum of four individual Sinbad skinks observed at one time. In 2014, there were 45 observation periods with a maximum of three individual Sinbad skinks observed at one time.

Table 2. Summary statistics for environmental data collected and used for analyses.

Variable	n	Mean	Standard error	Range
Air Temperature (°C)	146	15.04	0.36	4.3-25
Sunshine Minutes	146	8.25	0.57	0-15
Wind Speed (ms^{-1})	146	1.52	0.1	0-6.7
Humidity (%)	146	63.84	1.5	28-92.3
Rock Temperature (°C)	146	16.43	0.53	3.2-41.4
Barometric Pressure (kPa)	146	884.2	0.46	879.1-896.1

(Abbreviations: n= number of observations)

Spearman's rank-order correlation test was run to compare environmental variables that appeared to show high correlation with each other on lattice graphs. Only one correlation was strong enough to prompt concern about the use of variables as factors in the model and that was the relationship of shade air temperature and rock temperature (Rho = 0.7). Booth et al. (1994) suggest a value of 0.7 is a strong correlation. The simplest method to account for high correlation between predictor variables is to remove one of the variables from analyses to avoid masking potential effects of predictor variables on skink observation rates (Zuur et al. 2010). Therefore shade air temperature was removed from models as rock temperature has proven more important in other Oligosoma species (Coddington and Cree 1997).

Table 3. Comparison of the "full model" that includes all predictor variables and possible relationships and other possible models produced including the "best model" selected based on the lowest AIC value.

Model	Formula	df	ΔAIC
Full Model	glm(PropObs ~ Time + BaroPress + SunMin + Humidity + RockTemp + WindSpeed)	143	2.041
Alternative Model 1	glm(PropObs ~ BaroPress + SunMin + Humidity + RockTemp + WindSpeed)	143	0.75
Alternative Model 2	glm(PropObs ~ SunMin + Humidity + RockTemp + WindSpeed)	143	0.33
Best Model	glm(PropObs ~ Humidity + RockTemp + WindSpeed)	143	0

(Abbreviations are: df=degrees of freedom; ΔAIC=Relative Akaike Information Criterion value; PropObs=proportion of skinks observed from maximum number seen at one time; Time=time of day; BaroPress=barometric pressure; SunMin=sunshine minutes)

Models were initially investigated using possible linear and quadratic effects. However, intercepts and AIC values produced by such models were considered too large therefore only linear effects were included in final models. Based on data collected between 2012-2013, the best model (AIC=31.78) identifies humidity (coefficient = 0.035, s.e. =0.014) as having a statistically significant ($p=<0.05$) relationship with skink observation rates. The best model also identifies rock temperature (coefficient = 0.047, s.e. = 0.040) and wind speed (coefficient = -0.223, s.e. = 0.184) as having relationships worthy of inclusion in the model.

Predicted observation proportions based on the best model all increase relatively quickly (Fig.5). Observation proportions are predicted to reach 1 at rock temperatures of about 18.4°C, at a relative humidity of about 66% and at a wind speed of about 3.8m/s.

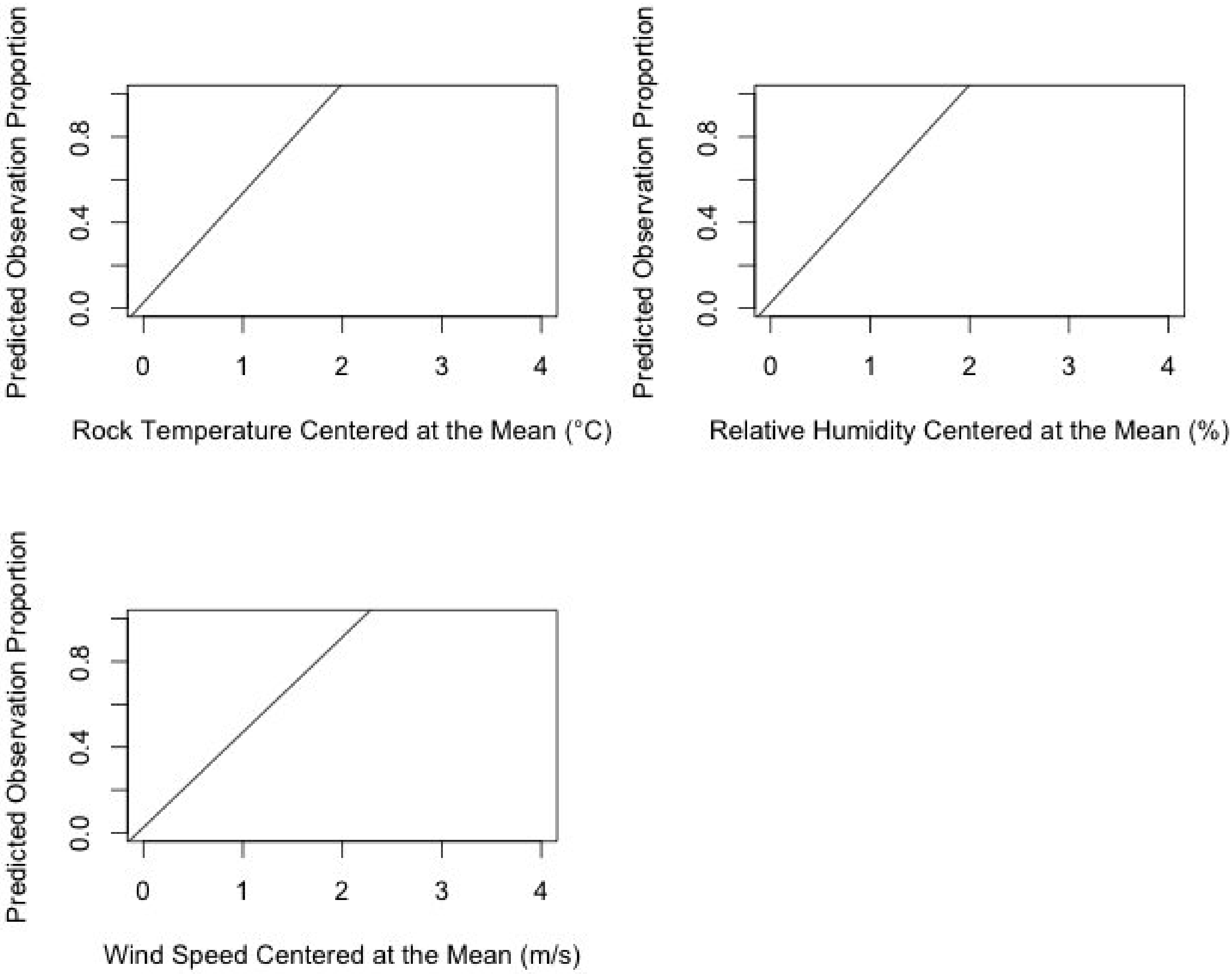

Figure 5 – Predicted observation proportions of Sinbad skinks for each weather variable (when all other variables were held at a reference level close to observed medians) included in the best model with weather variables centered at the means.

5.4 Discussion

The model created indicates that, as expected, there are relationships between weather variables and Sinbad skink observation rates. Variables identified by the best model as being correlated to observation rates were rock temperature, relative humidity and wind speed. Relative humidity had particularly strong correlations with skink observation rates. Based on the collected data, the best model identifies that the highest proportion of Sinbad skinks at Sinbad Gully will be observed when rock temperature is about 18.4°C; relative humidity is about 66%; and wind speed is 3.8m/s (Fig. 5). Although it must be stressed that these are correlations and not factors of causation, this is valuable information as it can be used to more efficiently guide and standardise future annual survey efforts (Hoare et al. 2009). Efforts can be concentrated to times when conditions with the identified rock temperatures, humidity and wind speed are expected, maximising probability of detecting all Sinbad skinks present and minimising variability (Hoare et al. 2009). However, there are a number of limitations involved with this study that will be discussed further in this report, so findings should be accepted simply as a tentative guide and a positive first step to further understanding Sinbad skinks.

The results of this study are comparable with other species where correlates of emergence have been analysed such as grand and Otago skinks (Coddington and Cree 2007). Rock temperature was identified as the most influential predictor for emergence of grand and Otago skinks (Coddington and Cree) and the best model suggests a high degree of relation between rock temperature and emergence for Sinbad skinks also. The other variables identified as having strong relationships with Sinbad skink emergence (relative humidity and wind speed), have also all been identified as influential predictors of skink movements in other Oligosoma species (Coddington and Cree 1997; Hoare et al. 2009). It must be highlighted that air temperature was removed from analyses in this study due to high correlation with rock temperature, so air temperature is likely to be related to Sinbad skink observation rates.

Other studies have also identified variables such as time of day, barometric pressure and sun exposure to be strongly related to Oligosoma skink movements (Coddington and Cree 1997; Hoare et al. 2009). Time of day, barometric pressure and sun exposure were omitted from the best model for Sinbad skinks. However, it would be foolish to discount them as important variables at this stage, particularly considering alternative models including other variables were inferior by <2 ΔAIC (Table 3) which suggests each model is well matched in explaining observed data (Mazerolle 2006). The model predicts observation rates to increase very quickly at certain weather conditions. Furthermore, it is possible that other covariates not measured during Sinbad skink surveys have correlations with observation rates i.e. wind direction. Wind direction can impact environmental conditions. Based on experience at Sinbad Gully, a southerly wind can create a wind chill factor. Also, wind direction dictates whether droplets from nearby waterfalls are sporadically sprayed over the survey area which could impact on Sinbad skink emergence. Wind speed and sunshine minutes should still be measured in any further research and the measurement of other variables that may be correlated to skink emergence should also be explored.

There were a number of limitations to this study, most notably the small sample sizes with only 145 data points from the three years of surveys. This is due to the limited conservation attention and, consequently, funding that Sinbad skinks have received, coupled with the logistically challenging Sinbad Gully site. With a small sample size, the observed correlations may not be representative of true relationships, hence why it is stressed results of this study should be accepted with caution.

The issue of underrepresentation is magnified by the fact that surveys are restricted to one small ledge site that may not be representative of all Sinbad skinks. Roughton and Seddon (2006) speculated that relationships between detectability and weather variables for their study of Otago skinks may have been masked by only surveying during relatively calm and sunny weather with no extremes experienced. This is potentially an issue for Sinbad skink surveys also, as due to the isolated nature of Sinbad Gully and the requirement of helicopters for access, surveys are undertaken in relatively fine weather. Models produced were simple with only linear effects being included. Due to a lack of data, quadratic effects could not be confidently identified. A concentrated survey effort at only fine conditions resulted in a lack of data at the more marginal and extreme conditions, likely masking some relationships. The presence of only linear relationships is unrealistic, for example skinks are known to emerge once temperatures reach a certain point however they also seek refuge at higher temperatures, a quadratic effect.

One solution that could allow a greater magnitude of data collection and increased representation is the use of camera traps. If camera traps can be developed to successfully capture Sinbad skink emergence, then they could be deployed along with a weather station at the site and left running for an extended period. This would provide data from a greater range of conditions and allow more robust models and detection probabilities to be estimated. Use of camera traps would also address another potential bias, observer presence. Anecdotally, Sinbad skinks appear to bask and move naturally without being perturbed by a stationary observer at a distance of >2m however, it is a bias that should be considered.

Another potential limitation is the variation in the timings of surveys between 2012-2014. Although no yearly trends were evident, the 2012 survey was in mid-February, the 2013 survey was in late February and the 2014 survey was in early March. The maximum number observed at one time in 2012 was four while in 2014 it was three, only a small difference but this may be important. Skink behaviours are known to change seasonally (Germano 2007) and movements in relation to weather variables of Sinbad skinks in early February could be different compared with early March, but a small sample size may have masked this effect. Future long-term annual studies should aim to complete surveys within as close a period as possible year to year and/or the seasonal behaviours of Sinbad skinks should be explored.

A factor worth further research is the effect of weather conditions from days preceding surveys. Coddington and Cree (1997) proposed preceding days may influence grand and Otago skink emergence behaviours. I speculate that after a period of poor weather, Sinbad skinks may emerge in more marginal conditions to take advantage of any sun and warmth available. Being opportunistic could be an important adaptation for the survival of an alpine skink as the climate is a lot harsher in the alpine zone of Fiordland. The effect of weather conditions from preceding days on Sinbad skink observation rates is worth further consideration.

Methodology could be vastly improved if individual Sinbad skinks can be identified. In this study, the minimum number of Sinbad skinks observed had to conservatively be considered as the maximum number of Sinbad skinks observed at one time. Photo-identification has proved a valuable monitoring tool for a number of Oligosoma skink species, using variations in patterning to distinguish individuals (Barr 2009; Gebauer 2009; Reardon et al. 2012). If individual Sinbad skinks can be identified then more accurate estimations of the minimum number of skinks observed during surveys can be obtained, and consequently more robust proportions of observed skinks calculated (Hoare et al. 2013). It is recommended that the viability of photo-identification for Sinbad skinks should be assessed, determining whether there are sufficient distinguishing features and variation of patterning between individuals.

The model created indicates that weather variables do have a relationship with Sinbad skink emergence. It was identified that rock temperature , wind speed and particularly relative humidity strongly correlate with Sinbad skink observation rates. This information can be used to guide future surveys. Based on the best model, surveys should be implemented when: rock temperatures are ~18.4°C; wind speeds are ~3.8 m/s; and when relative humidity is ~66% in order to maximise detection and minimise variation. It is recommended however, that these findings should be tentatively accepted as relationships have likely been masked due to limitations such as small sample size, unknown impacts of preceding weather conditions on skink movements and the absence of potentially important covariates. Further research should focus on locating more Sinbad skink survey sites, collecting a greater magnitude of data and assessing detectability in more representative conditions of the alpine zone. It is proposed that development of photo-identification and camera trapping techniques could be valuable tools for Sinbad skink conservation. Although lacking robust analyses, this study has provided a basis for further research and is a positive first step in the conservation of Sinbad skinks.

6. Additional points of note from fieldwork

During the three day period spent surveying Barrier skink habitat at Cheviot Faces, Takitimu Mountains, Southland, there were a number of observations and findings worth noting simply due to how little is known about the Barrier skink.

6.1 Barrier skink distributions at Cheviot Faces

Perhaps the most important finding not aforementioned in this report is that the known distribution of Barrier skinks at Cheviot Faces has been extended. Previous surveys had observed a maximum of nine Barrier skinks on a single day at Cheviot Faces (Edmonds 2009; Lettink 2010). The minimum number of individual Barrier skinks seen in a single day during the three days spent surveying in 2014 was on day 1 where 22 were observed while >30 were observed on day 2 and >25 on day 3. Previous surveys had only observed skinks within a 50x50m area at Cheviot Faces at ~1240m ASL (Edmonds 2009; Lettink 2010). During this survey Barrier skinks were observed right from the edge of dense vegetation where the scree pockets begin at about 1170m ASL to near the ridgeline at about 1400m ASL (Fig. 6; Fig. 7).

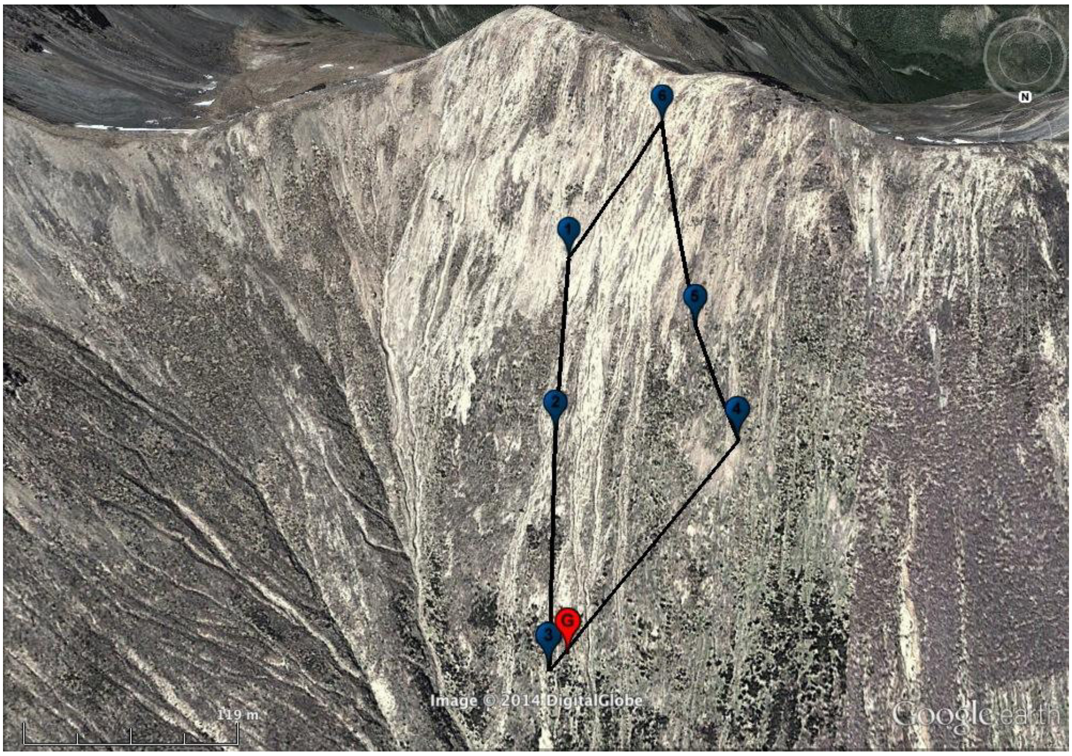

Figure 6 – Satellite image (Google 2013) of Cheviot Faces site with the outermost points at which Barrier skinks were observed labeled 1-6. The area defined by the black line encompasses all Barrier skink observations during field work from 24-28 January 2014. The point marked "G" is where a Cascade gecko was discovered. Coordinates for marked points are listed in Appendix I.

Figure 6 – Satellite image (Google 2013) with topographic overlay of Cheviot Faces site with the outermost points at which Barrier skinks were observed labeled 1-6. The area defined by the black line encompasses all Barrier skink observations during field work from 24-28 January 2014. The point marked "G" is where a Cascade gecko was discovered. Coordinates for marked points are listed in Appendix I.

Neighbouring scree slopes were briefly surveyed with no Barrier skinks being observed. This may be due to less optimal aspect, however a greater search effort is required. The extension of the known distribution of Barrier skinks at Cheviot Faces indicates that they may not be as specialised as initially believed.

6.2 Pests at Cheviot Faces

As an additional opportunistic investigation, four heat triggered Acorn trail cameras were set up within Barrier skink habitat and left running from the first day of the field work at Cheviot Faces until the end of Day 5. Two trail cameras were baited with venison meat and two were not baited to see if this had an impact on pest sightings. Only one image of a pest was captured by any of the cameras over the five days and this was of a possum in the night at one of the baited cameras. While surveying the Barrier skink habitat, scat from deer, pigs, stoat and possum were all observed confirming that the Barrier skink population is persisting despite the presence of a number of mammalian pests at Cheviot Faces.

6.3 Barrier Skink behaviour

One baited Acorn trail camera captured two Barrier skink sightings and the other baited trail camera made six Barrier skink sightings while the non-baited cameras did not make any sightings. Interestingly, at the trail camera with six skink sightings, a Barrier skink was captured on the footage picking up a piece of venison bait and taking it away before coming back and taking another piece away.

While surveying, other interesting Barrier skink behaviours were observed. At one site, three adult Barrier skinks were observed basking tightly together and then followed each other off into the scree under the same rock. Patterson and Bell (2009) suggested Barrier skinks may be gregarious at Barrier Knob due to the limited deep crevices available and the observed behaviour at Cheviot Faces suggests anecdotally that Barrier skinks may be gregarious there also. Territorial/hierarchical baehaviour was also observed, on one occasion an adult Barrier skink was observed chasing a juvenile away from under a rock and on another occasion two adult Barrier skinks were observed fighting and chasing each other away from a scree pocket.

6.4 Mites

While handling Barrier skinks at Cheviot Faces for the photo-identification trials, one skink was observed to have several mites parasitising the hind left limb axial and the front right limb axial.

Figure 8– Ectoparasitic infection of a Barrier skink at Cheviot Faces, Takitimu Mountains, Southland (Photo: Emmanuel Oyston).

It is natural and common for a proportion of an Oligosoma skink population to be parasitised by mites (Reardon and Norbury 2004), however mites can be transferred from species to species. Mites can negatively impact the fitness of Oligosoma skinks (Hare et al. 2010) so it may be of importance to apply further research into determining whether the ectoparasites infecting Barrier skinks at Cheviot Faces are native or introduced (possibly by common or mahogany skinks) to the population and to determine the impact the mites have on Barrier skink fitness.

6.5 Discovery of a gecko species at Cheviot Faces

While surveying for Barrier skinks, at the lower reaches of the scree face where vegetation begins to become thick, a gecko was found underneath a rock. There had previously not been any known sightings of any gecko species at Cheviot Faces. Only one gecko was found and it is believed to be a cascade gecko (Mokopirirakau "Cascades") at ~1200m ASL (Fig. ???; Fig ???). This adds to the known herpetological diversity of Cheviot Faces and is another known locality for the Nationally Vulnerable cascade gecko.

7. Report Conclusion

This report has highlighted how far we have to go in the conservation of New Zealand's alpine skinks. It has, however, provided a step forward. Kinopta's Blackeye 2W cameras are not suitable for alpine skink monitoring but with developments, camera trapping has potential as a valuable tool in monitoring alpine skinks. This study has importantly identified that photo-identification is likely to be a viable option for use in Barrier skink monitoring and population estimates. The modeling of Sinbad skink observation rates based on weather variables is a promising tool for guiding future field efforts and for understanding the ecology of alpine skinks. Also, some valuable points have been gained through field efforts such as the extension of known Barrier skink distributions at Cheviot Faces, some behavioural observations and the discovery of cascade geckos at Cheviot Faces. Barrier and Sinbad skinks are charismatic and intriguing members of New Zealand's herpetofauna but are in urgent and deserving need of increased conservation attention if we are to secure their future.

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10 Appendix

10.1 Appendix I

Coordinates for Barrier skink observations and Cascade gecko discovery marked on Fig. 6 and Fig. 7.

Marker on Fig.1	Latitude	Longitude
1	45° 64’ 44.61”	167° 80’ 68.38”
2	45° 64’ 33.39”	167° 80’ 69.94”
3	45° 64’ 19.63”	167° 80’ 70.78”
4	45° 64’ 31.8”	167° 80’ 52.35”
5	45° 64’ 38.71”	167° 80’ 55.91”
6	45° 64’ 52.77”	167° 80’ 58.29”
G	45° 64’ 20.35”	167° 80’ 68.97”

10.2 Appendix II

Coordinates recorded for some of the Barrier skinks observed at Cheviot Faces, Takitimu Mountain Range Southland between 24-28 January 2014.

Latitude	Longitude
-45.64373	167.806708
-45.64422	167.806813
-45.643625	167.806765
-45.643442	167.806679
-45.642857	167.80665
-45.64323	167.806231
-45.643164	167.807054
-45.643975	167.806824
-45.644007	167.806895
-45.643248	167.806828
-45.643322	167.806779
-45.643789	167.806658
-45.643867	167.80667
-45.643521	167.805624
-45.643136	167.806946

Latitude	Longitude
-45.643158	167.80695
-45.644117	167.806616
-45.642075	167.806904
-45.643807	167.806576
-45.643909	167.806346
-45.643702	167.806612
-45.643548	167.806665
-45.643313	167.806735
-45.643073	167.806817
-45.643011	167.806934
-45.642732	167.806993
-45.642227	167.806825
-45.642228	167.806774
-45.642477	167.806479