Automated Light Beam surveys: a remote monitoring technique for Bogong moths in alpine areas.

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Above photo: Remote monitoring equipment for Bogong moths set up in the field (Photo: Naomi Monk).

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Summary

The annual migration of Bogong moths, *Agrotis infusa,* between the inland plains of eastern Australia and the alpine areas provides a crucial food source for many threatened alpine species, such as the Mountain Pygmy-possum. At Falls Creek, Mt McKay is one of the mountain top locations where *A.infusa* spends the summer. The moths are a known main dietary component for Mountain Pygmy-possum population at Mt McKay, especially during the possum's breeding season. The number of *A.infusa* arriving to alpine areas can vary greatly between years and various methods have been used to monitor the relative abundance of *A.infusa* arriving to mountain areas, with the labour-intensive method of light trapping being the most commonly used.

This study demonstrates how the remote monitoring method of Automated Light Beam (ALB) surveys can be used effectively to collect robust data about the relative abundance of *A.infusa* at Mt McKay with minimal effort. At Falls Creek, it is recommended that an annual ALB monitoring program be implemented near the Mountain Pygmy-possum habitat of Mt McKay and Ruined Castle, complemented by occasional light trapping if required. It is also recommended that this methodology be considered by the other Alpine Resorts and Parks Victoria as part of a long-term coordinated monitoring program to identify changes to *A.infusa* abundance over time and identify triggers for threatened species action.

Introduction

Populations of Bogong moths, *Agrotis infusa* (Boisduval) (Lepidoptera: Noctuidae), migrate each spring from the inland plains of eastern Australian to the mountain tops of the Great Dividing Range to aestivate over the summer (Common, 1954) before returning to these inland areas in autumn to breed (Green, 2010). These migrations to the mountains usually occur at night (Drake and Farrow, 1985) and after the moths have arrived in the mountains, they may also repeatedly emerge from their aestivation sites to take flight at night (Common, 1954). Whilst not only crucial for the life cycle of the moth, the annual arrival of moths to the mountains brings nutrients to these areas as the moths are a crucial food source for many high elevation animals (Green, 2011), including the Mountain Pygmy-possum (Smith and Broome, 1992; Weeks et al., 2021). A decline in the observations of Bogong moths in alpine areas has occurred in the past decade. This has raised concern for the future survival of many alpine species that may rely on the Bogong moths as a food source. This was particularly the case for the Mountain Pygmy-possum which was observed to have pouch young litter loss in populations during years when moth numbers were low and highlighted the importance of gaining long-term data of the Bogong moths arriving to alpine areas (DELWP, 2019).

The detection rates of *A.infusa* depends on the methodology used, with some methods such as transect surveys, not suitable at all for monitoring this species of moth (Monk, 2020). The suitability of different methods used to monitor *A.infusa* can be impacted by the topography of the site and weather conditions (Monk, 2020). A variety of different methods have been used to monitor *A.infusa* in alpine areas (e.g. Common, 1954; L.Broome pers. comm.; D.Heinze, unpub.; P.Mitrovski 2009, unpub.), with light traps being the most commonly used method. Light traps can be highly variable in their ability to detect moths likely due to micro-scale site specific features (Monk, 2020). Furthermore, light traps are labour-intensive requiring daily checks, unable to operate in high winds, and costly. Light beam surveys provide an alternative to light traps, with trials in 2019-20 suggesting that this method provides consistent detectability and could be automated, warranting further investigation to determine its suitability for use in a long-term monitoring program (Monk, 2020). Light beam surveys suit the typical flight behaviour of *A.infusa* of flying metres above the ground (N. Monk, pers. obs.).

Given the remote locations of many of the *A.infusa* aestivation sites in alpine areas it would be useful to have a robust automated monitoring program that is easy to execute and does not need to be visited daily. Furthermore, the reduced number of moths means that any monitoring program ideally should occur with minimal impact to the moths and be non-destructive. Automated light beam (ALB) surveys offer benefits to address these issues as they can be left in the field for weeks and do not physically capture any moth in the recording. Thus, the aim of this study was to determine if light beam surveys could be conducted using automated equipment and whether this method was useful for detecting relative abundance of Bogong moths in alpine areas throughout the aestivation period. The study involved the design, testing and evaluation of this remote monitoring equipment, alongside traditional light traps for comparison.

Methods

ALB equipment design

An automated light beam (ALB) was designed for the remote monitoring of Bogong moths arriving to the mountain tops using the light beam survey approach that was successfully manually tested during the previous season (Monk, 2020). To do this, the ALB monitoring equipment is designed to trigger the light beam on for a series of five 1-minute sampling intervals each night at a set time after sunset. At the same time as the light beam is being triggered a camera is activated to record video. The ALB is powered using a 12V battery that is housed within the same box as the monitoring equipment.

Design of the ALB involved considerations including weather proofing, security, safety to users and the environment, cost, ease of replaceability of parts, and ease of data processing. The cost, excluding labour, of the components used in the construction of the ALB came to approximately $260 (Appendix 1). Components are housed in a weatherproof plastic container that sits inside a wooden frame on which the spotlight is mounted (Figure 1), the wooden frame has handles to allow for easy carrying to site.

Figure 1. Components of the Automated Light Beam (ALB) monitoring device.

Site details

The study took place at Mt McKay (1835m ASL) in Falls Creek Alpine Resort, located in north-east Victoria (Figure 2). The climate is typically cool with high levels of precipitation, intermittently falling as snow mostly between the months of June and September. Mean annual precipitation is 1308 mm, while mean maximum monthly temperatures during the spring and summer is between 4.9 °C and 17.9 °C, with mean minimum monthly temperatures between -0.8°C to 8.9°C (Bureau of Meteorology, 2021). *A.infusa* has been observed aestivating in the spring and summer months in the rocky boulder fields and outcrops at Mount McKay (N. Monk, pers. obs.).

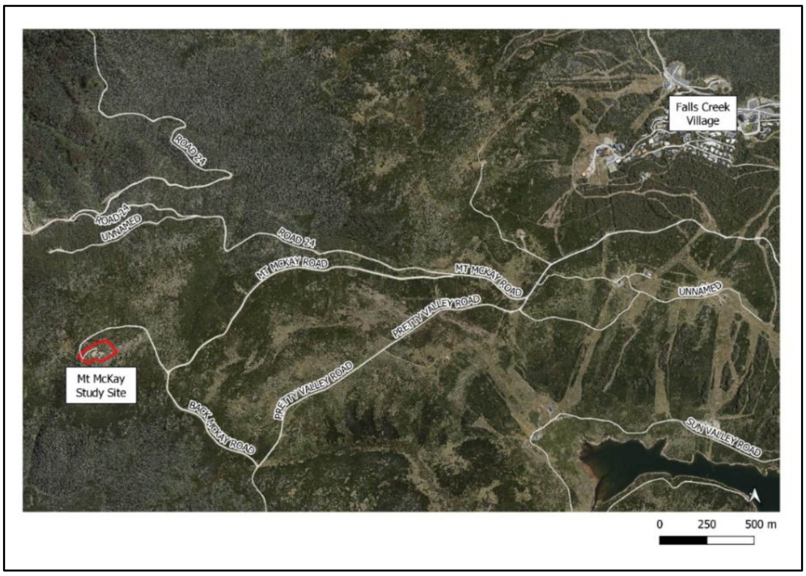

Figure 2. Bogong moth *Agrotis infusa* monitoring study site within Falls Creek Alpine Resort, Victoria, Australia.

Sampling design

The study occurred from October 2020 to March 2021 to align with previously observed *A. infusa* arrival and departure times (Monk, 2020). Sampling times were within the period of a week before or a week after a new moon to reduce the influence of moonlight (Beck & Linsenmair, 2006; Morton, Tuart & Wardhaugh, 2009; Yela & Holyoak, 1997). A total of 15 monitoring sessions occurred (22 Oct 2019; 16-18 Nov 2019; 15-16 Dec, 12-14 Jan 2021; 16-18 Feb 2021; 16-18 Mar 2021) for a maximum of three consecutive nights, where possible. During each monitoring session there was one ALB and two light traps set within the study area. The light traps were set at the same two locations that had been randomly selected from a grid in the year prior (Monk, 2020) and the ALB site was selected randomly at a distance to not be likely to interfere with the light traps at a similar elevation. The two light traps and one ALB were set at the same sites on every occasion. Selection ensured that each site was at least 20 m from each other to avoid any the methods from impacting on each other (Truxa and Fieldler, 2012).

All monitoring equipment was set to activate 45 minutes after sunset to align with the activity period observed of the first moths between 0-40 minutes after sunset (Monk, 2020). Temperature and weather conditions were noted using observations from the nearby Falls Creek weather station.

ALB surveys

ALB surveys were adapted from methods outlined in Common (1954) and Macgregor et al. (2017). The ALB has a bright (3486 lumens spot beam, distance of up to 378 m), narrow-beamed (beam diameter at 5 m is approximately 5 m) solid LED spotlight. This light was positioned at ground level pointing directly upwards towards the sky. The light was activated using a timer (Jaycar 12VDC Digital Mains Timer Switch Module) that also activated a video camera (Nextech 1080p Dash Camera) able to capture within its view the entire light beam. The light and camera were activated for five one-minute intervals spaced by one-minute 'off' periods.

Later the data was downloaded from the camera and manually processed by counting all *A.infusa* passes (determined by being the appropriate size and moth shape) through the light beam during each minute of recording. Two counting methods were trialled firstly all moths seen both brightly lit and dull were counted, secondly only the brightly lit moths were counted. This was to determine whether just counting the more easily seen, brightly lit moths could provide a good indication of relative abundance.

Light traps

Two insect black light fluorescent bucket base traps (12 Volt 8 Watt; Australian Entomological Supplies Pty Ltd.) were set to activate for one hour using a timer (Figure 3). There are no permanent artificial lights on Mt McKay and sampling times were selected to minimize moonlight. Traps were checked early the following morning. The number of *A.infusa* were counted individually for each trap along with any other species of arthropod before being released back into the nearby habitat.

Figure 3. Light trap set up in the field.

Data analysis
To compare the trend of relative abundance over the season detected by the ALB and light trap for each of the monitoring methods the relative abundance was converted into the proportion of the overall count measured for each method. To compare the two data processing methods trialled for the ALB the proportion of bright passes compared to all detected passes (bright and dull) were calculated to determine whether this was consistent over the season.

Results

Timing of migration
A.infusa had clearly arrived at the time of the first monitoring session on the 22nd October 2020. Most of the moths had left Mt McKay by the last monitoring session on the 18th March 2021, with a total of only 10 moths being recorded using the ALB for this date. Over the 15 monitoring sessions, a total of 3354 *A.infusa* were observed across both ALB (bright and dull count) and light trap counts. During the monitoring sessions temperature fluctuated greatly, wind direction varied, and weather conditions included fog, drizzle and rain. Analysis of weather conditions did not reveal any trends with moth numbers.

Timing of arrivals
The timing of the peak in relative abundance detected differed between the methods, with the ALB peaking in November and the light trap peaking in December. This peak in December for the light traps was due to the once off event of 925 moths caught on one night in one light trap. The lower proportion detected in December by the ALB was likely due to rain on the 16th December affecting the visibility of moths on the camera.

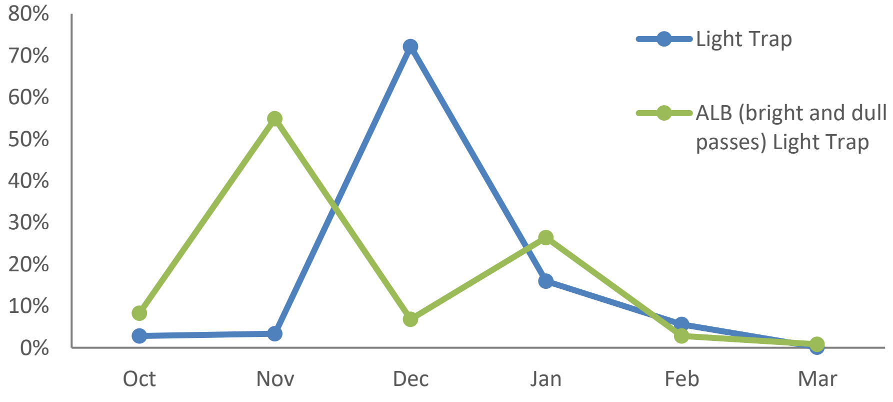

Figure 4. Proportion of total *A. infusa* recorded by each method (ALB - bright and dull passes, Light traps) per monthly monitoring session.

The number of moths detected on each night of sessions within the same month differed with both the ALB surveys and light traps having some fluctuations in the average number of moths observed within each of the monitoring sessions (Figure 5). These fluctuations didn't always follow the same trends, for example in January the ALB observed a slight variation in the number of moths and the light traps observed a dramatic decrease over the same nights.

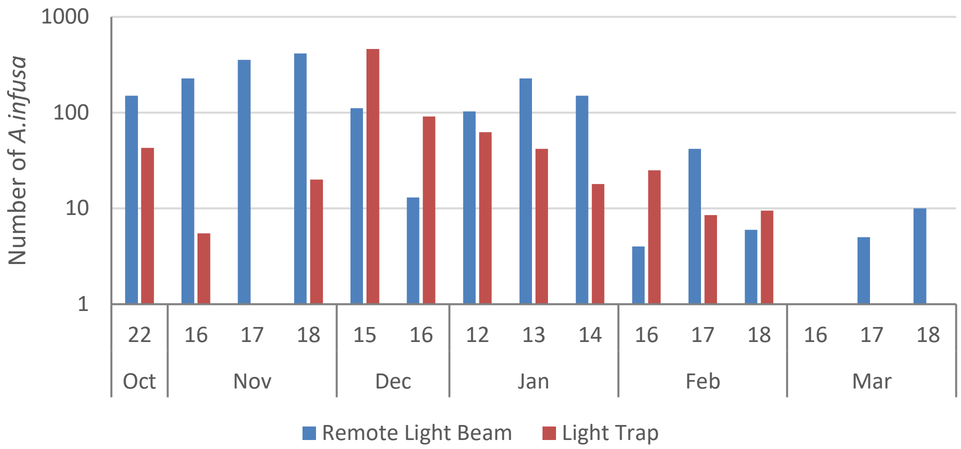

Figure 5. Number of A.infusa detected on each night monitoring session within the same new-moon monitoring month using the ALB and light traps.

ALB surveys

A total of 1820 bright and dull illuminated moth passes were observed, and of these 1129 were brightly illuminated passes. A mean of 55% of all passes were brightly illuminated passes (range 20% to 67%). The proportion of brightly illuminated moths was lowest during the month of March when moth numbers were few. The brightly lit moths were easy to detect on a computer screen and therefore quickly tallied (Figure 5).

Figure 5. Image from video recording showing three brightly illuminated *A.infusa* circled in yellow (note: one dull A.infusa is also in the image circled in green)

Light traps

Similar to previous findings, there were dramatic differences between the number of *A.infusa* captured by each of the light trap replicates depending on the surrounding habitat (Monk, 2020) (Figure 6). The variability that occurs when attracting moths using light traps suggests that the method is susceptible to micro-scale variation and/or the inability to detect technical issues without being on-site during operation (Figure 6).

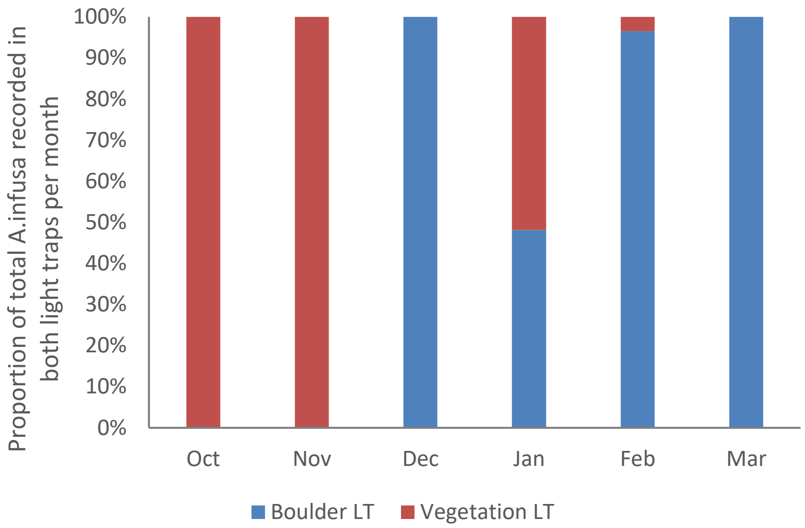

Figure 6. Proportion of total *A. infusa* recorded for each month during the monitoring season 2020-21 of the two different micro-habitat light traps (boulders vs vegetation) (note: Due to equipment issues, October had only Vegetation LT in operation).

Despite efforts to secure the vanes, the light traps failed at times when wind speed was high (Figure 5a). During some monitoring sessions, one light trap would have many moths whilst the other would have none, for example in December one trap recorded no moths on both nights, whilst the other trap recorded 925 *A.infusa* and 182 *A.infusa*. It is uncertain whether this large variation in moths detected is due to micro-habitat differences alone or equipment failure such as the light not activating. The traps that did attract moths often had moths found under the battery box (Figure 5b), suggesting that the light had attracted the moths towards the bucket but then not lured them close enough to be successfully captured and therefore counted. This is further supported by observations of the moths at night around the lights traps whereby the moths tended to fly erratically around the lights rather than directly towards it.

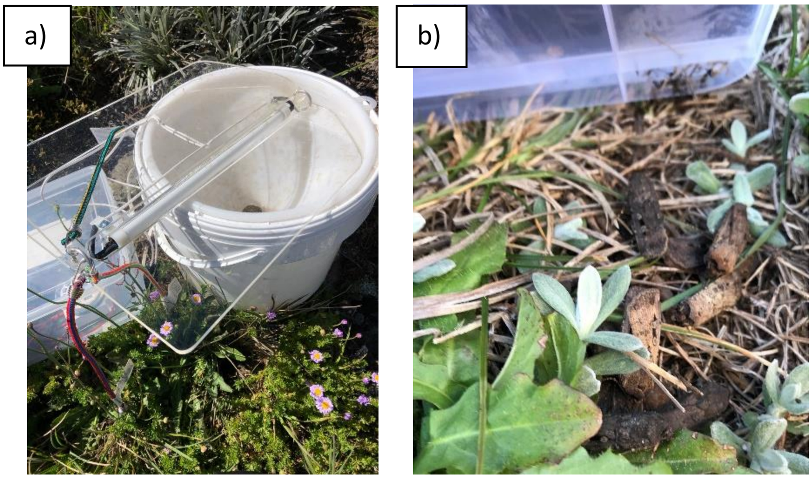

Figure 5.a) One issue of the light trap is the vanes can be knocked over in high winds meaning it is difficult to know whether the lack of *A.infusa* detected was actual or due to equipment failure, b) *A.infusa* were often found under the battery box near the light trap.

Discussion

This study has demonstrated that light beam surveys can be successfully conducted for *A.infusa* using automated equipment. The ALB survey method was useful for detecting the change in relative abundance of *A.infusa* at Mt McKay throughout the aestivation period, indicating a peak in numbers at the end of Spring/start of Summer and very few *A.infusa* remaining in March. The study involved the design, testing and evaluation of this ALB monitoring equipment, finding it to perform well in most weather conditions except for in heavy fog and rain. The ALB equipment was able to be left in the field for extended periods of time without needing any maintenance. When operated alongside traditional light traps for comparison, the ALB had numerous benefits, including the ability to detect any equipment failure, being able to operate during high winds, and having minimal labour involved. In contrast, light traps were highly variable in detection rates and were likely influenced by micro-scale site-specific features present at a location. ALBs were able to detect moths during most sessions across all months, even in March, indicating that this method is sensitive enough to detect very low numbers.

There are a few considerations for implementing a wider monitoring program using ALB surveys including equipment considerations, timing, and processing. Equipment considerations include ensuring the ALBs are fully charged and able to operate for a lengthy period in the field and using a memory card in the video camera that can record multiple survey sessions without needing changing. Currently the ALB timers are adjusted to activate 45 minutes after sunset, which requires changing monthly. This changing of the timer could be done to align with charging the battery and changing of the memory card. ALBs would be left out in for a minimum of one week per month, ideally longer, to provide the best chance to obtain robust data. The results suggest that counting the brightly illuminated moths is a reliably useful method to use in processing the data. Processing of brightly lit moths is relatively quick and can be done either in-house or by setting up a citizen science monitoring program to assist, alternatively it may be possible to use artificial intelligence software (such as ImageJ) to count the moths.

Comparisons between ALB surveys and light traps

The ALB method captures a considerable distance into the night sky and therefore would unlikely be affected by micro-scale habitat variation. The light trapping did suggest it was affected by micro-scale differences, however unlike last year's light trapping, the light trap detection wasn't always higher at the vegetated site. Whilst there was often a higher number proportion of moths captured in one of the two habitat types, except for in January, the habitat type with the higher proportion changed over the months. The reasons for this are unknown.

Light traps were labour intensive, requiring setup prior to sunset and then an early revisit the following morning to count and release moths. The traps also need to remain active for longer than the ALBs making them more visible to the public at night when activated and at risk of being tampered with. Light traps cannot be operated in heavy rain or in high winds.

In summary, ALBs are easy to set up and leave in discrete locations. ALBs only activate for a short period of time and are therefore less likely to cause a disturbance to the moths and to other nocturnal animals at a site. Data can be stored and reviewed at a convenient time with multiple monitoring sessions being processed together, minimizing workload. The data processing has the possibility of being automated using software programs that can count images. The objective data that is gathered enables processing to be carried out by different observers without bias.

Recommendations

To best inform land management and identify potential risks to threatened species such as the Mountain Pygmy-possum, FCRM needs to have robust methods to easily and efficiently monitor the relative abundance of *A.infusa* arriving throughout the migration season and over time. ALBs enable data to be gathered with minimal disturbance to *A.infusa* and other nocturnal animals. This data, when combined with threatened species population data, can assist in making informed decisions about interventions.

It is therefore recommended that:

- FCRM conduct ALB surveys between the months of October and March at the long-term population monitoring Mountain Pygmy-possum sites of Mt McKay and Ruined Castle.
- The ALB be left out for a minimum of one week to ensure the chance of being able to detect in good weather is increased.
- Reporting should include only the brightly illuminated moths, ensuring that processing time is kept to minimum.
- The viability of using artificial intelligence software to process the brightly illuminated moths be explored.
- Light traps be used only as needed for confirming species identification or to further understand micro-scale habitat effects.

It is also suggested that ALB methodology be considered for Bogong moth monitoring programs in the other Alpine Resorts and in the National Park.

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Appendix 1. Component list for construction of ALB

Detail	Component	Jaycar part no.	Quantity	Cost ($)
Wiring	UNDER DASH DOUBLE CIGARETTE LIGHTER Socket	CAT.NO: PS2009	1	14.95
Wiring	Cigarette Lighter Plug - FUSED	CAT.NO: PP2001	1	4.95
Light	3486 Lumen IP68 Solid LED Spot Light	CAT.NO: SL3919	1	59.95
Camera	1080p 2 Inch Car Dash Camera	CAT.NO: QV3845	1	49.95
Timer	12VDC Digital Mains Timer Switch Module	CAT.NO: AA0361	1	59.95
Battery	12V 9Ah SLA Battery	CAT.NO: SB2487	1	44.95
Housing	Container 5.5L		1	8
Wooden box	Sourced parts		1	10
Wiring	Miscellaneous cable and connectors			10
Total				$262.7

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