Investigating monitoring techniques for estimating the relative abundance of the migrating Bogong moth Agrotis infusa to alpine areas

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Research Report

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Front cover photo: A Bogong moth *Agrotis infusa* (Photo: Naomi Monk).

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Contents

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. The number of *A.infusa* arriving to alpine areas can vary greatly between years. Various methods have been used to monitor the relative abundance of *A.infusa* arriving to mountain areas; however, these approaches have been varied in methodology, location and timing. This study aimed to document, for the first time, the relative abundance of *A.infusa* arriving at Mt McKay in the Falls Creek Alpine Resort, whilst also investigating the most efficient and effective way to monitor *A.infusa* relative abundance over time. Four methodologies were investigated: 1) light traps, 2) time-lapse photography, 3) light beam surveys, and 4) transect surveys. There were noticeable differences between the detection rates of *A.infusa* depending on the methodology used. Whilst the transect survey was not suitable for counting *A.infusa*, the light trap, time-lapse photography and light beam monitoring methods were able to detect the same basic level of presence or absence of *A.infusa* on each monitoring date. The light trap, time-lapse and light beam methods all indicated that *A.infusa* had arrived by the end of October 2019 and had left Mt McKay by the 3rd March 2020. Light traps were highly variable in *A.infusa* detection rates and were likely influenced by the micro-scale site-specific features present at the sampling location. Time-lapse photography was variable in its detection rates suggesting that it may be unable to detect differences of relative abundance between months. Light beam surveys tended to provide a more consistent observation rate within each monthly session suggesting it may provide a method that is less vulnerable to confounding fluctuations. The possible automation of light beam surveys along with careful consideration of site location may enable a robust, long-term monitoring program to be implemented with minimal effort to assist with understanding long-term changes to relative abundance in A.infusa arriving to mountain areas. Such monitoring may be of increasing importance for predicting ecosystem changes with future climate change. A strengths, weaknesses, opportunities, and threats (SWOT) analysis for each method is provided as an appendix to this report.

Introduction

Bogong moths, *Agrotis infusa* (Boisduval) (Lepidoptera: Noctuidae), fly annually in spring from the western inland plains of eastern Australia to aestivate in the cooler alpine areas along the Great Dividing Range (Common, 1954). The moths then return to these inland areas in autumn to breed when food resources are suitable for their larvae (Green, 2010). Mass migrations usually occur at night (Drake and Farrow, 1985) with moths using the earth's magnetic fields to orientate themselves (Dreyer et al., 2018) towards the alpine areas of the Australian Capital Territory, the Victorian Alps and the Snowy Mountains in New South Wales. The moths engage in a period of aestivation whereby they delay maturity and mating during a summer in alpine areas (Green, 2006, Common, 1954). This annual migration forms an important nutrient cycling role in alpine areas and is a crucial food source for many high elevation animals (Smith and Broome, 1992, Green, 2011). In recent years, incidental observations of decreased moth numbers at high altitude areas in Victoria has identified a possible threat to the survival of the many alpine species that depend on the moth as a food source (DELWP, 2019).

The numbers of *A.infusa* reported arriving to aestivate along mountaintops varies annually (Common, 1954; Caley and Welvaert, 2018). Despite *A.infusa* arriving to numerous alpine areas along the Great Dividing Range, there has been very few formal scientific monitoring programs to document the abundance of moths. Some monitoring has occurred using various data collection methods within alpine areas of New South Wales, Australian Capital Territory and Victoria (DELWP, 2019). Anecdotally, large numbers of *A.infusa* have historically arrived within Falls Creek Alpine Resort, with many locals recalling years with large numbers arriving within the resort village. During the spring/summer of 2018-19, low numbers of *A.infusa* were observed to arrive at both at Falls Creek and nearby Mt Hotham (N. Monk, pers. obs.), highlighting the need for a wider monitoring program to be implemented (DELWP, 2019).

Along with the flight migration to mountain tops, *A.infusa* also have a tendency to engage in nightly activity periods whereby the moths exit their aestivation refugia temporarily to take flight for short periods before returning (Common, 1954). Monitoring techniques that target flying moths may provide an efficient way to gain an understanding of the relative abundance of *A.infusa* both arriving and currently occupying an area for aestivation at any one time. Mountaintops are typically characterised by extreme weather, including high winds, large temperature changes, snow/hail, and frost, which poses challenges in the use of accepted methods for insect monitoring (e.g. light tents).

A variety of site-specific methods have been used to monitor *A.infusa*, including tracking the changes in areas occupied by populations on mountain cave walls (Common, 1954), counting the number to pass in front of a car headlight shone vertically into the sky (Common, 1954), operating bucket insect light traps for varying lengths of time (L.Broome pers. comm., D.Heinze, unpub.) and bucket traps (P.Mitrovski 2009, unpub.). These methods can be difficult to apply at different sites to enable comparisons to be made between sites. To enable a repeatable, simple long-term monitoring program to be implemented across multiple sites, approaches are needed that are robust to varying weather conditions, are simple to execute, and can be easily repeated across multiple investigations.

Methods yet to be tested for monitoring *A.infusa* that may be robust and simple to execute include transects, modernized light beam surveys and time-lapse photography. Night-time transects have the benefits of requiring minimal equipment and can produce a more efficient capture rate of moths per hour compared to light trapping (Macgregor et al., 2017). Whilst light beam survey counts have been used for *A.infusa* using older technology (e.g. Common, 1954), there is evidence that more user-friendly modern equipment can been used to monitor moths(Macgregor et al.,2017). *A.infusa* can be observed as silhouettes against the light of the setting sun at dusk (N. Monk, pers.obs). Consequently, time-lapse photography using cameras aimed at the setting sun may allow for capture of moth activity in an area without the need for an observer to be present at night.

The purpose of this methodology study was to collect data on the relative abundance of *A.infusa* arriving in Falls Creek Alpine Resort, contributing to data being collected during the same moth migration season on Mt Hotham and Mt Buller using light traps (Claire Hutton, unpub.). The study also aimed to investigate the most efficient and effective way to monitor *A.infusa* relative abundance over time by trialing four methodologies: 1) light traps, 2) time-lapse photography, 3) light beam surveys, and 4) transect surveys.

Methods

The study took place within Falls Creek Alpine Resort, located in north-east Victoria. The research area was around the highest peak within Falls Creek Alpine Resort, Mount McKay (1835 m ASL) (Figure 1). 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 1,273 mm, while mean maximum monthly temperatures during the spring and summer is between 4.8 °C and 17.9 °C, with mean minimum monthly temperatures between -0.9°C to 8.9°C (Bureau of Meteorology, 2019). Large numbers of *A.infusa* have been observed aestivating in the spring and summer months in the rocky boulder fields and outcrops at Mount McKay (N. Monk, pers. obs.).

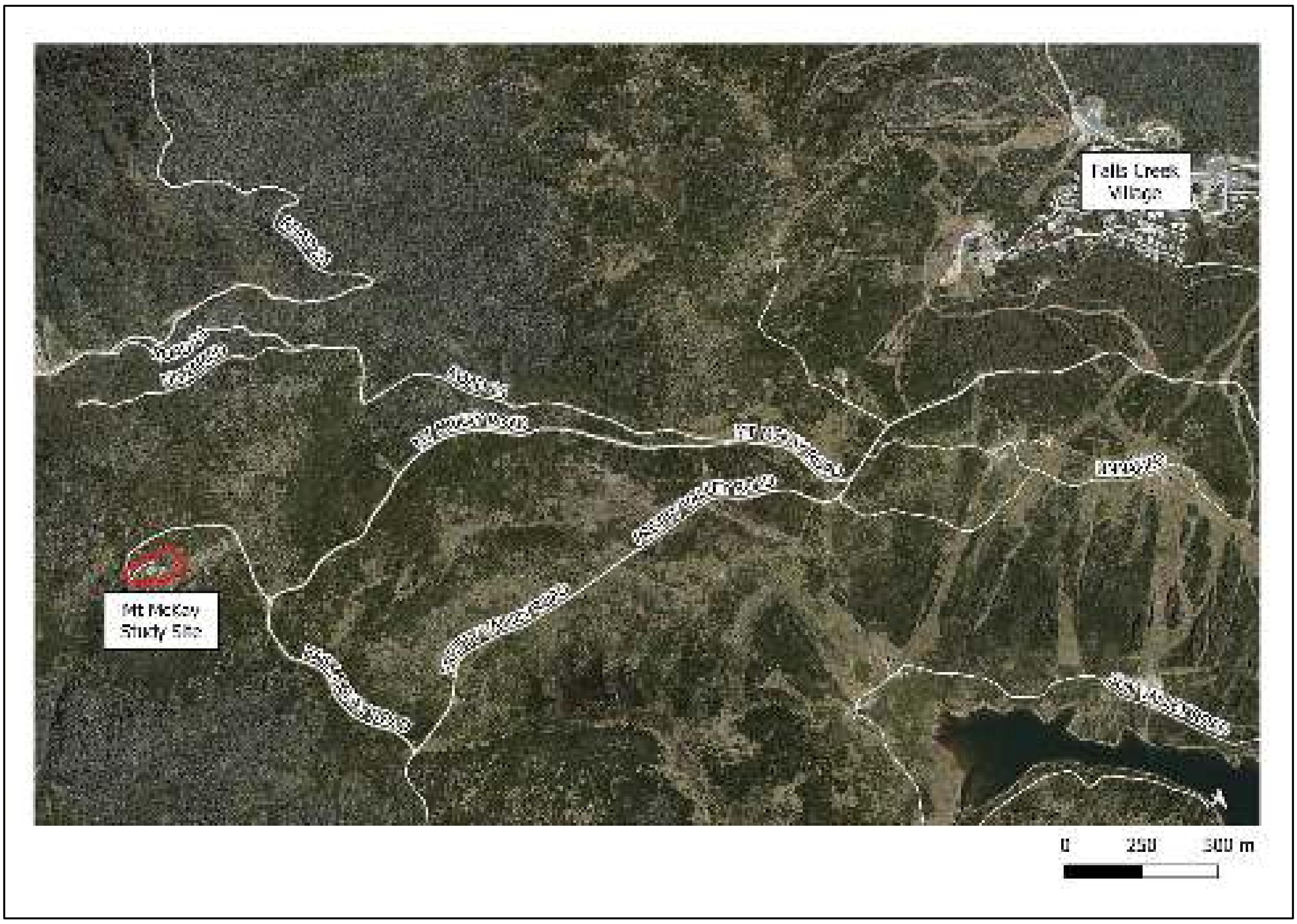

Figure 1. Bogong moth *Agrotis infusa* monitoring study site within Falls Creek Alpine Resort, Victoria, Australia.

The study occurred from October 2019 to April 2020 to align with previously observed arrival times at the end of September (Green, 2011) and beginning of October (N.Monk 2018, unpub.) and departure times around February (N.Monk 2018, unpub.). 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 10 monitoring sessions occurred (29-31 Oct 2019; 27-28 Nov 2019; 2 Jan 2020; 28-30 Jan 2020; 3 Mar 2020) for a maximum of three consecutive nights, where possible.

Each method was deployed at the same site every session. These sites were randomly selected from a grid laid across Mt McKay summit area adjacent to rocky boulder field known to typically support aestivating moths. 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 occurred at 45 minutes after sunset (with the exception of the 2nd January session that occurred 30 mins after sunset); this aligned with the activity period observed of the first moths being seen between 0-40 minutes after sunset (n=10, $\bar{x}$ = 24 min). Temperature and light level data were collected during the monitoring sessions. Four Hobo data loggers were attached to each of the time-lapse cameras and to each of the light traps, ensuring that the light sensor was exposed to the sky. The temperature and lux levels were recorded every 10 minutes over the hour monitoring session. The data was then processed by recording the average temperature and lux level for each logger for each session. Light levels were 0 lux for the entire time at all sites during the monitoring sessions and the UV-light from the light traps was not detected by the light loggers. Additional information, such as current weather conditions and cloud cover, were noted on each date as these may influence flight activity of the moths (Merckx & Slade, 2014; Jonason et al. 2014).

Time-lapse photography

Two Reconyx Hyperfire cameras were set to activate for one hour starting 45 minutes after sunset. The cameras were set against rocks in the field at an angle of 60 degrees towards the direction of the setting sun (Figure 2). Photos were set to trigger every minute. These images were then analysed by recording the count of moth silhouettes per image and tallying these for each camera.

Figure 2. Time-lapse photography method set up.

Light traps

Two insect black light fluorescent traps (12 Volt 8 Watt; Australian Entomological Supplies Pty Ltd.) were set up to activate 45 minutes after sunset (30 minutes after on 2 January) for one hour using a timer (Figure 3). There were no permanent artificial lights on Mt McKay and moonlight levels were minimal, ensuring that the effectiveness of monitoring moths using light traps was not decreased by other light sources

(Eisenbeis, 2006; Nowinszky et al. 2012). Traps were checked either that night or immediately the following morning. The number of *A.infusa* were counted individually for each trap along with any other species of arthropod (with photos taken of other species to assist with identification). Those captured were then released back into the nearby habitat.

Figure 3. Light trap set up, in LT1 in boulders (left) and LT2 in vegetation (right).

Mark-recapture was trialed by applying a small amount of food dye using a small paintbrush to the wings of a few *A.infusa*. Food dye was used as it was the least likely option to have any toxic effect on any animal that might predate on *A.infusa*. Blue, red and yellow dyes were trialed; however the food dye did not effectively stain the moth scales and was repelled when applied at varying dilution strengths. Following this trial, no mark-recapture occurred during the study given there had been no other possible marking medium that had been identified.

Transect surveys

A night-time transect survey was conducted one hour after sunset along a 25 m marked line. The methodology for these surveys was adapted from that used by Macgregor et al. (2017). The 25 m transect was divided into 5 m intervals at which a floodlight fitted with a red filter was placed on the ground pointing upwards (Macgregor et al., 2017). Any moths seen at each 5 m interval were to be captured using a hand butterfly net with the aid of a headtorch for one minute before moving onto the next 5 m interval and repeating until the end of the transect was reached. The transect was repeated three times with the total number of *A.infusa* at the end of each transect recorded.

Light beam surveys

Light beam surveys were adapted from methods outlined in Common (1954) and Macgregor et al. (2017). A bright (140 lumen for a distance up to 160 m), narrow-beamed (beam diameter at 5 m was approximately 1.3 m) head torch (LED-Lenser) was positioned approximately one metre above the ground pointing directly upwards into the sky. Over the period of one minute, all *A.infusa* passes through the beam were counted. This was conducted by an experienced observer that identified *A.infusa* by shape, size and flight behavior; however, it is possible that some counts may not have been *A.infusa*. Light beam surveys were repeated four times, spaced by one minute of darkness whereby the head torch was turned off. The total count for each minute was recorded.

Data analysis

To analyse the trends detected by each of the monitoring methods, the data was made comparable by converting the relative abundance into a proportion of all counts for each method. The proportion counts used the medians for each monitoring session and therefore removes any variation that occurs due to a reduced number of replicates on a date. The percentage observed of the total *A.infusa* observed during each monitoring session was calculated for each method to enable comparisons in the fluctuations of observations to be identified.

Results

Over the 10 monitoring sessions, a total of 748 *A.infusa* were observed in light traps, 132 moths silhouettes recorded on the time-lapse cameras and 1056 overhead moth passes were counted during the light beam surveys. The transect survey method did not capture any *A.infusa*. Therefore the transect method was determined to be not effective as *A.infusa* typically flew too high and quickly to be captured using the butterfly net and was not lured down towards the spotlight when removal of the red-filter was tested. For this reason, the transect method was only used during the October monitoring sessions and abandoned due to its inefficiency to capture the target species.

Temperature fluctuated greatly between monitoring sessions and the number of moths observed did not seem to vary according to temperature (Figure 4). The only time that the first moth was seen immediately after sunset occurred was on 27 November 2019 when the temperature was at the coldest mean temperature observed of all the sessions at 5 °C.

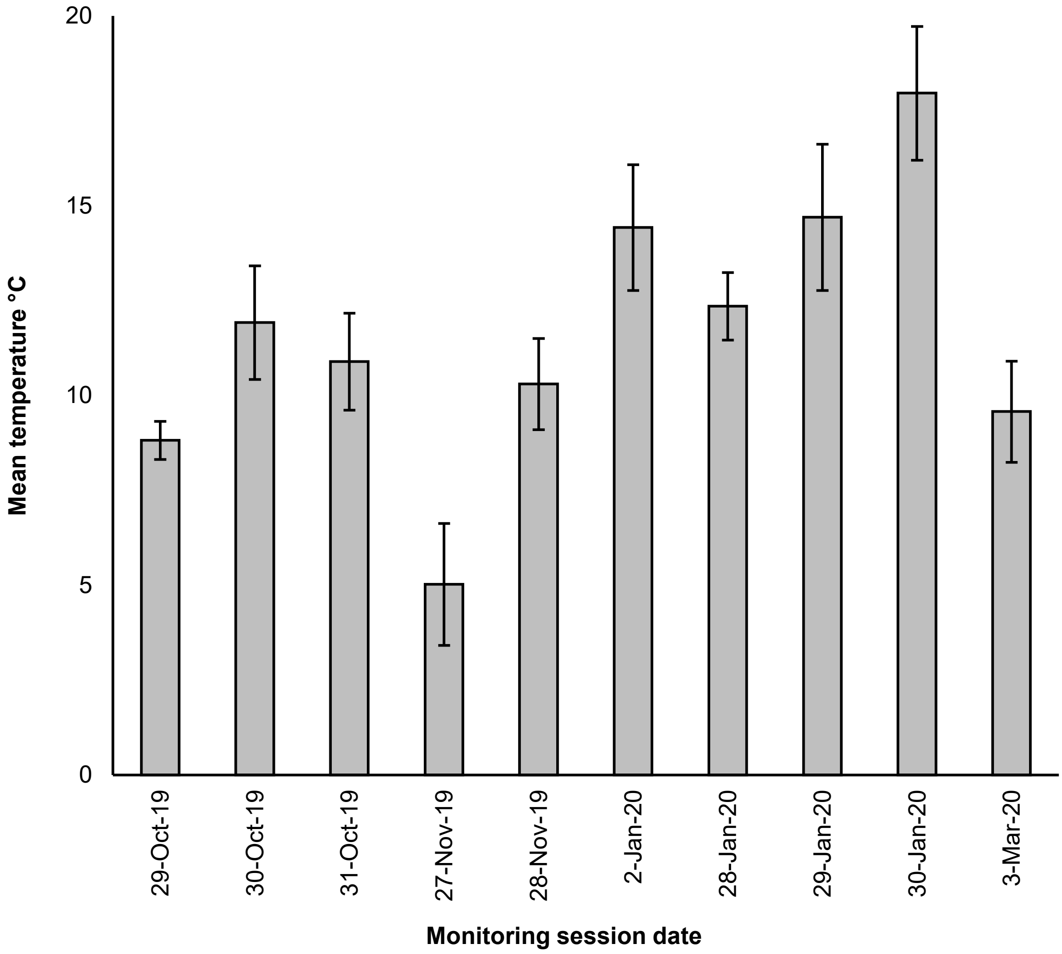

Figure 4. Average temperature across the monitoring sites during each monitoring session.

There were dramatic differences between the number of *A.infusa* captured by each of the light trap replicates (LT1 and LT2) during every monitoring session (Figure 5). The random grid selection located LT1 between large boulders greater than one metre in size, whilst LT2 was positioned in an area surrounded by low native shrubs and herbs with only a few small boulders smaller than one metre in size. LT2 was not active during the first two monitoring dates of October 29th and 30th and on both of these monitoring sessions, LT1 recorded one *A.infusa*. The light trap that was positioned in native vegetation had the highest total number of *A.infusa* recorded during every session that the two light traps were active (Figure 5), with total counts that ranged from 4 times to up to 133 times that observed at LT1 positioned in boulders. The two light traps did not follow similar trends across the monitoring dates.

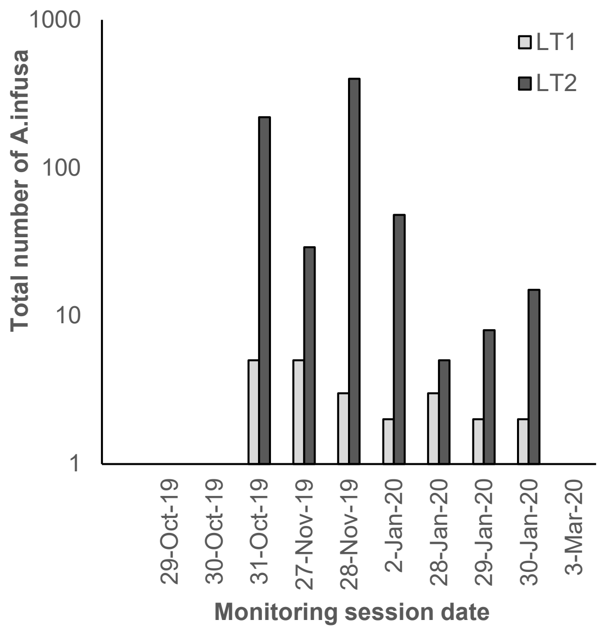

Figure 5. Total *A.infusa* recorded at each light trap on each monitoring date. LT1 positioned near boulders, LT2 positioned in native vegetation. Note: LT2 not operational on 29-30 October 2020.

The light trap, time-lapse photography and light beam monitoring methods were able to detect the same basic level of presence of *A.infusa* on each monitoring date. These three methods all indicated that moths had arrived by the end of October 2019 and that by the 3rd March 2020 there was no *A.infusa* remaining on Mt McKay. These methods show a definite decline in moth numbers around the end of January but differ in the magnitude of decline that occurred at the beginning of January.

The peak in relative abundance differed between the methods, with the time-lapse indicating that the peak occurred in October, whilst the light beam and light trap methods both indicated that the peak number of *A.infusa* was the end of November (Figure 6). Interestingly, the light beam method detected the most *A.infusa* on the cooler night of the 27th November 2019 when the light trap method detected very few moths. This highlights the variability in detection of each method with the light beam focused on the high-flying individuals above one metre, whereas the light trap method focused effort within a restricted area at ground level.

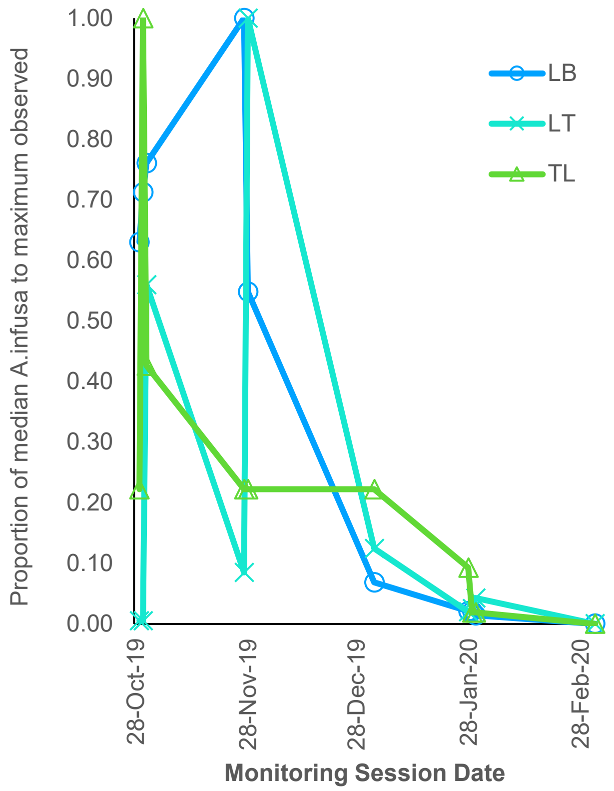

Figure 6. Proportion of *A. infusa* to maximum over each month of monitoring for the Light Beam (LB), Light trap (LT) and Time-lapse (TL) monitoring methods.

The change in the number of *A.infusa* over time was different for each method with some methods having dramatic fluctuations between dates within the same new-moon monitoring period (Figure 7). When grouped by the new-moon monthly sessions, both the light beam and light trap methods showed a similar trend of numbers increasing in October to peak in

November before a decrease in early January with a further decrease at the end of January. The time-lapse method did not follow this trend due to lower detections in November than in October. Time-lapse had the highest proportion to maximum observed in the October monitoring session which was also when light beam and light trap recorded comparably high proportion counts above 0.50 (LB=0.76, LT=0.56).

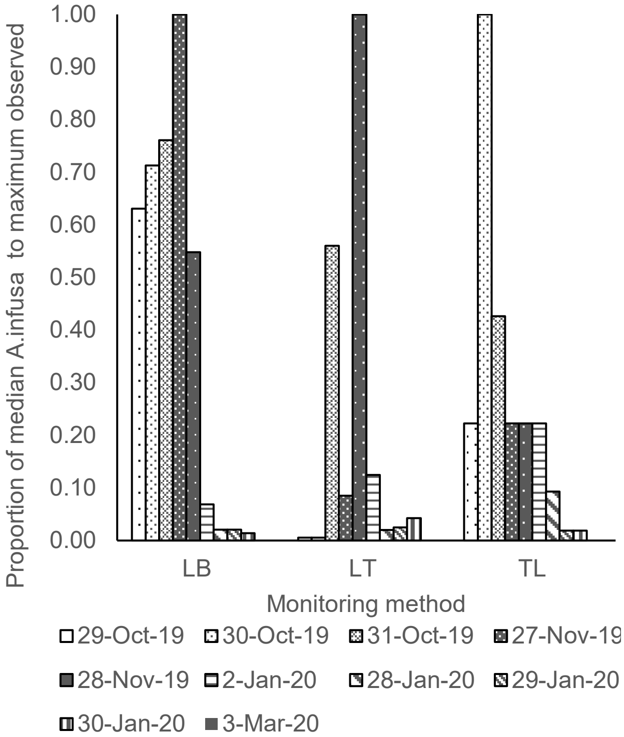

Figure 7. Proportion of *A.infusa* to maximum observed during each monitoring session for the Light Beam (LB), Light trap (LT) and Time-lapse (TL) monitoring methods.

Each method had different trends in the percentage observed of total moths for each date that the monitoring occurred (Figure 8). However, when grouped by the new-moon monthly monitoring sessions, both the light beam and light trap methods did reflect the similar trend seen in the proportion of median *A.infusa* to maximum observed with numbers increasing in October to peak in November before a decrease in early January with a further decrease at the end of January. The light beam method had the least dramatic fluctuations in the percentage of total moths observed between the monitoring sessions within each of the same new-moon monthly monitoring groups (Figure 8), whilst the light trap method had the greatest amount of fluctuation. The time-lapse method had the same percentage of total moths for one of the October dates, both November monitoring dates and the monitoring occurring in early January (Figure 8). This differed from both the light beam and light trap methods that detected differences in the percentage of total months between these dates.

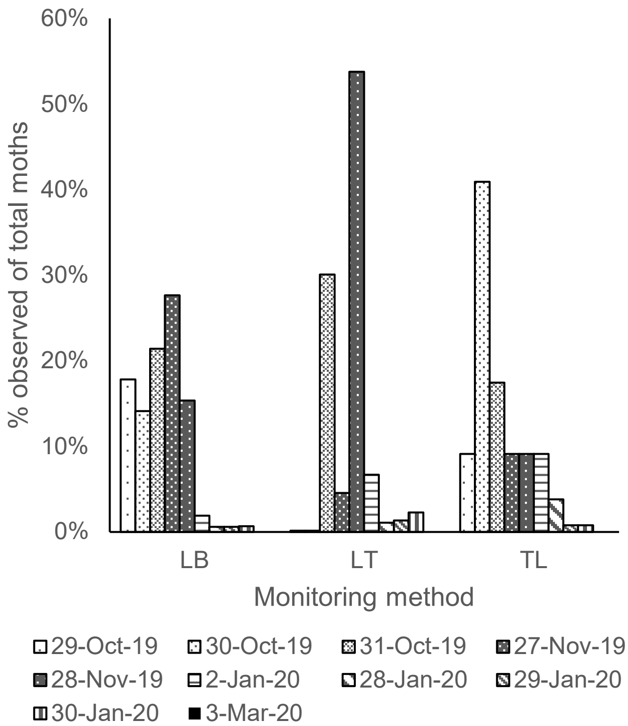

Figure 8. Percentage observed of total *A.infusa* observed during each monitoring session for the Light Beam (LB), Light trap (LT) and Time-lapse (TL) monitoring methods.

Discussion

There was noticeable differences between the detection rates of *A.infusa* at Mt McKay depending on the methodology used. Whilst the transect survey was determined to be not suitable for counting *A.infusa*, the light trap, time-lapse photography and light beam monitoring methods were able to detect the same basic trends across the season. The light trap, time-lapse and light beam methods all indicated that moths had arrived by the end of October 2019 and had left Mt McKay by the 3rd March 2020. The research indicates that light traps are highly variable in detection rates suggesting that this is likely influenced by micro-scale site-specific features present at a location. The time-lapse method was variable in its detection rates suggesting that it may be unable to detect differences of relative abundance between months. Light beam surveys tended to provide a more consistent observation rate within each monthly monitoring session suggesting it may provide a method that is less vulnerable to confounding fluctuations, although it may be vulnerable to observer error.

Timing of observations

The data suggests that *A.infusa* aestivating in Victorian areas may depart earlier than those in the NSW mountain tops. Caley & Welvaert (2018) reported most moths had left by early March with remainder having left by April, which was one month earlier than the dense streams observed departing during early April by Common (1954). Common (1954) hypothesized that temporary influxes that occurred at Mt. Gingera during February and March were due to moths migrating north from the mountains farther south. Further investigation into the migration route of returning *A.infusa* during the autumn migration could identify any possible crucial temporary stopover sites for the species. The nightly timing of *A.infusa* activity detected at Mt McKay reflected that observed by Common (1954) indicating that the peak in nightly activity begins to occur around 20-30 minutes after sunset. However it must be noted that not all *A.infusa* engage in nightly flights (Common, 1954), and therefore not all moths have the same possibility of being detected using these methods that observe only flying individuals.

Variation between methods

It is possible that the variable detection rates of light trap and time-lapse methodologies between dates is due to the amount of space that the moths are detected in, with smaller detection spaces more likely to be vulnerable to variation within a site. The light trap attraction distance for *A.infusa* is unknown; however, for moths it is typically very small often less than 10 m (Truxa and Fieldler, 2012). Based on the data, the time-lapse appeared to detect moths within a space of approximately 2 m wide up to a maximum of 5 m away from the camera. In contrast, the light beam survey had a capture area at least 1.3 m wide for over 50 m. Another likely reason for the variation in detection between methods is that the typical flight behaviour of *A.infusa,* which involves flying metres above the ground (N. Monk, pers. obs.), likely is best captured using the light beam method, rather than the light trap and time-lapse methods that are positioned on the ground. Further evidence for the avoidance of low flight occurred during the testing of the transect survey method.

Importance of site selection

The consistently higher number of moths recorded in the light trap at the vegetated site suggests that the placement position of the light trap is likely to influence measurements of relative abundance. It is possible that *A.infusa* uses hilltop vegetation, such as dense shrubs, for aestivation as well as using boulder outcrops. Along with the moth camps in boulder caves, temporary moth camps amongst fallen tree trunks and soil piles has been observed by Common (1954). Further research is required to determine if the low shrub vegetation growing on Mt McKay can provide suitable aestivation habitat. Another possible cause for the difference in moth trapping between the two light traps was the aspect that the trap was placed on the summit, as Common (1954) observed a possible preference by *A.infusa* at Mt Gingera for rock outcrops on south-western and north-western slopes. The light trap placed in vegetation was at a slightly more north-western aspect than the light trap placed in the boulders that was on a more northern slope. The outlying high number of moths recorded at the light trap in the vegetated site on the monitoring session of

November 28 indicates that, on this occasion, suitable conditions were occurring at this site, with an increase in air temperature being the main difference from the previous night's session.

Influence of weather conditions

Wind and light rain does not deter flight of *A.infusa* (Common, 1954). Therefore, methods that can be deployed in these conditions will likely provide an indication of relative abundance. The light beam surveys did not detect any decrease in relative abundance during the cooler temperature experienced on November 27th 2019, whilst the light trap method detected a large difference between the cooler night and the following night. Common (1954) observed that activity before evening flights in aestivation caves was reduced when temperatures were below 7 °C, meaning it is possible that the light beam was detecting both new arrivals and those engaging in activity flights whereas the light traps area of attraction favoured those engaging in activity flights. Likewise, light traps and bait traps have higher capture rates during warmer temperatures (Jonason et al., 2014; Yela & Holyoak, 1997). Bait traps are less affected by meteorological factors (Yela & Holyoak, 1997) and possibly worth further investigation. Monitoring occurred on one night during the bushfire period at the beginning of January 2020 when conditions were very smoky. The effect of smoke on *A.infusa* is unknown and the presence of *A.infusa* in smoky conditions suggests some tolerance to smoke.

Pros and cons of each methodology

The lack of success of the nightly transect method in capturing any *A.infusa* was unexpected given the previous success of this method (MacGregor et al. 2017). MacGregor et al. (2017) noted that this method might not be suited to strong flying moths and this research was not conducted in Australia where *A.infusa* is endemic. It is likely that the flight behaviour of *A.infusa* was not complementary to the nightly transect method, as the species was observed typically flying at least 3 m above the ground at the study site. This is further supported by Common's (1954) observations of *A.infusa* flight usually ranging 1.8 m to up to 24 m at higher elevations.

Light traps were best cleared in the morning after being activated rather than at night as the moths were much more active at night, making the processing of moths far more challenging. Light traps were labour intensive, requiring setup prior to sunset and then an early revisit the following morning to count individuals captured and separate species.. Over 15 other species of moths and at least 4 other insect species of varying abundance were found in the traps. The traps were easily seen by the public at night when activated and therefore were at risk of being tampered with. The light traps were weather-dependent and whilst being able to be activated during light rain, it is unlikely that the electrics would withstand heavy downpours. Similarly, it is unlikely that these traps could withstand high winds that are typical of alpine areas with these conditions being avoided during the study to prevent damage to equipment. Site location is likely to be very important for light traps with the effectiveness of the light as a lure diminishing rapidly with distance (Merckx & Slade, 2014). The strength of the light source is important to consider when undertaking light trap sampling as various light sources have different effects on different species (Beck & Linsemair, 2006; Jonason et al., 2014; Merckx & Slade, 2014). The attractiveness of differing light strengths and wavelengths has not been tested for *A.infusa* and warrants further research. Light traps were useful to track changes in other taxa abundance alongside *A.infusa* over a season.

Time-lapse cameras were easy to set up and leave discretely placed within the habitat. Data was able to be reviewed at a time that was convenient and numerous monitoring sessions could be saved to the one SD card without needing to be changed over. The images captured were often blurred from flight making it difficult to tell species apart, with *A.infusa* being recorded based on size and shape characteristics. The cameras were unlikely to detect anything at a distance greater than a few metres away. The cameras could be left out for the entire spring and summer to monitor variation in moth activity and provide an indication for relative abundance provided that detection levels were good. This method might be best suited to being positioned at the entrance to a known aestivation crevice, or to survey in more remote areas where nightly visitation is impractical.

Light beam surveys required very little technical equipment and relatively low total time input into obtaining the data (less than 15 minutes per day). These surveys required an experienced observer to be present for around 10-15 minutes each night after sunset, which can be late in the evening in the middle of summer. To be accurate, the method requires the observer to recognise the physical and flight characteristics of *A.infusa* and to not be distracted by other species that cross through the light beam such as microbats, other moths and beetles. During this study, all light beam surveys were carried out by the same observer to minimize observer error. If light beam surveys were to be used more widely, then variation due to different observers may be likely. These surveys could be conducted in any weather conditions, except for fog. A trial was conducted to test the possibility of automating the light beam survey and resulted in the development of a prototype design to be tested further next season. If successful, this prototype would assist with making the method more objective and enable surveys to be carried out without the need for an observer to be present at night by allowing the recorded light beam survey to be viewed at a later date.

Conclusion

Developing robust methodologies that easily and efficiently monitor the relative abundance of *A.infusa* arriving throughout the migration season and between years will likely improve the understanding of occupancy trends over time. As with all moth monitoring, any robust method employed will only reliably provide the relative abundance of a species and not absolute densities. The light trap, time-lapse and light beam methods all had success at detecting *A.infusa*. However, the methods vary in the level of A.infusa detectability and the effort required to implement them and process data. Whilst the light beam surveys tended to provide a more consistent observation rate within each monthly session, the method is vulnerable to possible observer error which may be controlled if this approach is able to be automated. The research highlights the possible micro-scale impacts of site selection on the data collected and should be considered during any future monitoring program design. Understanding long-term changes in the relative abundance in *A.infusa* arriving to mountain areas may be of increasing importance in predicting ecosystem changes under future climate change scenarios, especially as the *A.infusa* is an important food source for many alpine animals such as the Mountain Pygmy-possum.

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Appendix:

Strengths, Weaknesses, Opportunities, and Threats analysis of light beam, light trap, and time-lapse photography methodologies.

Light beam

S

- minimal equipment required
- minimal survey effort (>15 minutes)
- able to be used at any site
- can be deployed in most conditions, except fog

W

- requires human presence at night
- requires accurate time keeping and rapid counting
- difficult to distinguish between different species of moth
- risk of possible differences between observers

O

- possible to automate the process to eliminate weaknesses

T

- distractions (people, other insects)
- bright lights at the site

Light trap

S

- easy to purchase
- simple to set up (only some work required for timer)
- easy to distinguish between different species of moth

W

- unable to operate in rain and high winds
- batteries require charging regularly between sessions
- considerable cost per trap
- unable to detect fault with light if not present
- requires clearing of the trap each day

O

- use trail camera to get remote video footage to confirm operating times
- effective during warmer temperatures

T

- risk of being tampered with by public
- malfunction
- bright lights at the site

Time-lapse photography

S

- easy to set up
- can be deployed by anyone
- can be reviewed later
- suitable for all weather
- can be left set in field for months

W

- considerable cost per camera
- only small area of detection in front of camera
- difficult to distinguish between different species of similar sized moths

O

- placement near aestivation crevice may improve detection

T

- malfunction or flat batteries possible
- moths flying greater than a few metres from the camera