— Note on Methodology —

FROM BIRDS TO BEES: APPLYING VIDEO OBSERVATION TECHNIQUES TO INVERTEBRATE POLLINATORS

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Abstract—Observation is a critical element of behavioural ecology and ethology. Here, we propose a similar set of techniques to enhance the study of the diversity patterns of invertebrate pollinators and associated plant species. In a body of avian research, cameras are set up on nests in blinds to examine chick and parent interactions. This avoids observer bias, minimizes interference, and provides numerous other benefits including timestamps, the capacity to record frequency and duration of activities, and provides a permanent archive of activity for later analyses. Hence, we propose that small video cameras in blinds can also be used to continuously monitor pollinator activity on plants thereby capitalizing on those same benefits. This method was proofed in 2010 in the alpine in BC, Canada on target focal plant species and on open mixed assemblages of plant species. Apple ipod nanos successfully recorded activity for an entire day at a time totalling 450 hours and provided sufficient resolution and field of view to both identify pollinators to recognizable taxonomic units and monitor movement and visitation rates at a scale of view of approximately 50 cm^2. This method is not a replacement for pan traps or sweep nets but an opportunity to enhance these datasets with more detailed, finer-resolution data. Importantly, the test of this specific method also indicates that far more hours of observation - using any method - are likely required than most current ecological studies published to accurately estimate pollinator diversity.

Keywords: *alpine, diversity, pollinators, video observation*

INTRODUCTION

Behavioural ecology and ethology are sophisticated fields of research facing many challenges. The theories associated with these fields encompass ecology and evolution and often include predictions that are difficult to test particularly as they relate to coevolution or to inferring selection processes over time. More pragmatically, a significant challenge is to secure sufficient sample sizes whilst minimizing interference to the natural systems in question (Jennions & Møller 2003). Observation is thus a critical element to effective hypothesis testing in most aspects of these fields. A perfect example (and analogy to plant-pollinators) is the study of parent-offspring interactions in birds (Godfray 1995). Nests provide a focal point for observation, hatchlings and subsequently chicks develop and exhibit a range of behaviours (Krebs 2002) – all conveniently confined to the nest, resources are transferred in the system (Gottlander 1987), and the parents interact both directly with the young and indirectly through resource provisioning (Kolliker et al. 1988). Hence, the techniques used in these studies should be applied to plant-pollinator interactions at least as an addition to larger-scales surveys employed such as pan traps or sweep nets. Focal plants or groups of plants can be defined (the nest), observation can be applied at appropriate timeframes daily and throughout the flowering season (the hatchlings and chicks), and pollinator activity recorded throughout (the parents). This level of observation would provide novel insights to pollinator biology and plant-pollinator interactions.

Given current pollinator declines in diversity and abundance globally (Biesmeijer et al. 2006), effective tools and surveys at multiple scales are also critical for conservation. To date, research on plant-pollinator interactions use visual field observation by researchers in quadrats (Hegland & Totland 2005) or along transects (Dicks et al. 2002) or sometimes both (Olesen & Jordano 2002). Observations are often on a few focal plant species (Manetas & Petropoulou 2000) and generally take only a snapshot of activity in a given growing season. One comprehensive study observed pollinators every two weeks for twelve weeks (Kaiser-Bunbury et al. 2010), and observation intervals vary in length from five minutes (Dupont et al. 2003) to at most an hour (Ladd & Arroyo 2009). A recent related methodological study also examined the utility of observation for bumblebees using video motion detection triggers (Steen & Thorsdatter Orvedal Aase 2011). Hence, there is an opportunity in this field of research for more extensive, detailed surveys at finer-scales that would

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inform both estimates of diversity and abundance and provide information on the importance of plant-pollinator matching to better understand global declines.

METHODS

In a representative case study using birds, video cameras were successfully used to monitor resource allocation and behaviour of adults and nestlings (Budden & Wright 2008). Cameras were concealed or in blinds, extensive data were collected both in time and for all individuals, and the videos provided the capacity to record frequency, timing, duration, interactions, and resources provided. Adapting this approach, we tested Apple ipod nanos (5 th generation with 2.1 megapixel cameras) on focal plants in the alpine in BC, Canada to assess whether the method is effective under adverse field conditions such as the alpine. Nanos were shielded from view by pollinators using neutral coloured blinds with small openings. The blinds ensured that neither the metallic colour of the unit nor the screen were visible to the insects. The blinds also raised the cameras off the ground to varying heights so as to capture the maximum number of flowers. Ipod nanos have solid state drives so do not generate heat and have a long battery life. We tested 8GB nanos that provided at least 6 hours of continuous video with small supplementary battery packs attached to the connector dock pins at the bottom of the units. The total cost per unit was $200 although prices have subsequently decreased. A field of view of 50 cm ^{2} was tested for the entire length of the growing season in the alpine in BC (5 weeks) with up to 3-4 hours of peak pollinator activity captured on warm, sunny days. There were no unit failures or problems associated with the implementation of this technique in the field which was often a difficult and challenging site in many respects with both wind and fluctuating temperatures. We do recommend that at every 2-hour interval the units be checked as a built in feature sometimes end the recording (intact). As a test of focal species recording, the cushion-forming plant species *Silene acaulis* was selected, and to test general efficacy on vegetation, equivalently sized patches of groups of smaller species of alpine plants were also monitored.

RESULTS AND DISCUSSION

This video approach was highly successful. At 2 feet from the target plant(s), the 640 by 480 pixel resolution provided a clear, crisp image for pollinator observation including mites when present. A total of 450 hours of observation was recorded. Subsequent analysis of the video using Quicktime Pro 7.6.6 in real time provided the means to identify pollinators to recognizable taxonomic units and often species depending on the size of the insect. Movement, timing, visitation rate, visits to flowers versus time spent on non-flowering vegetation were also distinguishable (and when necessary we used pause and zoom functions for identification). Effective pollen transfer cannot be inferred from these videos however since we elected to monitor entire plants and not specific flowers. In summary, use of small, concealed cameras allowed us to define pollinator activity at a very fine-scale in the alpine and estimate diversity of pollinators and associations with specific plant species.

Sweep nets, pan traps, malaise traps, and nest boxes are common tools in pollinator surveys as a means to assess diversity and abundance. Here, we propose that an affordable and time effective solution or enhancement to estimate pollinator diversity is video monitoring at very localized scales. This approach can be applied to small patches of plants or to specific target plants (as is sometimes done in sweep net surveys). There are numerous advantages to this approach. It is very time effective (at least in field) in that cameras are set up and the researcher is free to conduct other research (not nearby). Observer and sampling-related effects such as interference in pollinator movement, disturbance via researcher movement through the site, or introduction of other biases such as pan trap colour, placement, or location are significantly reduced or eliminated depending on when cameras are applied. Importantly, more subtle interference effects are also avoided such as the Hawthorne effect whereby subjects often change behaviour when observer is present (Mayo 1949). Most compellingly in many respects is the sheer volume of data that can be collected. The pilot project proofed in 2010 is amongst the most comprehensive surveys published to date in terms of the total hours of similar observation studies on pollinators published to date (Dupont et al. 2003; Kaiser-Bunbury et al. 2010; Ladd & Arroyo 2009; Steen & Thorsdatter Orvedal Aase 2011), and we have the capacity to revisit the effects to record additional factors. Video has been used in other aspects of pollination biology such as nectar stealing (Marten-Rodrıguez & Fenster 2008), identifying nocturnal pollinators (Marten-Rodrıguez & Fenster 2008), responses to predatory spiders (Brechbuhla et al. 2010), and the biomechanics of pollen deposition (Whitaker et al. 2007) but never to diversity/abundance surveys of pollinators nor to plant-pollinator associations. Steen & Thorsdatter Orvedal Aase (2011) did similarly demonstrate that a motion detection camera was effective in capturing bumblebee visits on rhododendron flowers with a total test of 98.5 hours in monitoring. Taken together with our expansion both in terms of time, an additional 350+ hours, and plant species, tested on a large alpine plant and 12 other smaller plants, these general observation methods are clearly a novel tool in studying diversity. The motion detection approach is likely appropriate for larger insects whilst the approach we tested captures all insects - large and small - but resolution in identification for the smaller species is less refined. The set-up we tested is also far more portable for remote conditions than Steen & Thorsdatter Orvedal Aase (2011), but post hoc file review time is significantly longer. Hence, both approaches suffer trade-offs similar to other ecological studies i.e. detail versus scope, and the choice of method should coincide with purpose of the study. For community-level diversity estimates, we recommend the ipod nanos or other small solid-state cameras in blinds. An improvement to this methodology would be setting up more than one ipod on a given patch of vegetation (if the budget permitted). This would facilitate even more accurate tracking of movement of the insects and also clearly demarcate whether a visitor to a patch is unique or the same individual that moved out of the field of view of one of the two cameras. Another interesting addition to the methodology would be the use of micro-environmental sensors such as ibuttons that track temperature and relative humidity with timestamps and are also affordable ($30). Specific minute-by-minute activity could then be correlated with pollinator activity *in the field* thereby providing an excellent opportunity to understand the importance of fine-scale variations in climate.

There is also another critical advantage to this method. It provides a direct, quantitative means to assess efficacy in sampling. Only a single publication has explored this concept to date via a systematic review of the literature (Williams et al. 2001). Sampling efforts are most likely inadequate to accurately estimate pollinator diversity levels (Williams et al. 2001). Given the number of hours recorded in this preliminary video experiment, we applied a similar analysis to the dataset. Using rarefaction curves in EstimateS (Colwell 2010), we tested whether the sampling effort associated with recording activity on a single plant species (*Silene acaulis*) and assemblages of alpine plant species effectively estimated pollinator diversity. It did not. Over 200 hours were recorded on *Silene acaulis*, and there was no evidence of an asymptote in the number of recognizable taxonomic units, i.e. easily identifiable pollinator groups (Figure 1). On the mixed assemblages of plant species, over 400 hours were recorded, and there was also only limited evidence for an asymptote (Figure 1). These findings clearly indicate that extensive video observation is the only viable solution to effectively estimate pollinator diversity. This may seem bold, but it is a reasonable suggestion since (i) these estimates are conservative in that taxonomic richness was used and not species richness (which would be greater) and (ii) given that alpine pollinator communities are assumed to be less species rich relative to other systems (Wilson et al. 2010). In summary, while a bird in the hand is worth two in the bush, we propose that a bee on the camera is worth at least two - or more - in the net and that more comprehensive surveys are needed to be useful for conservation.

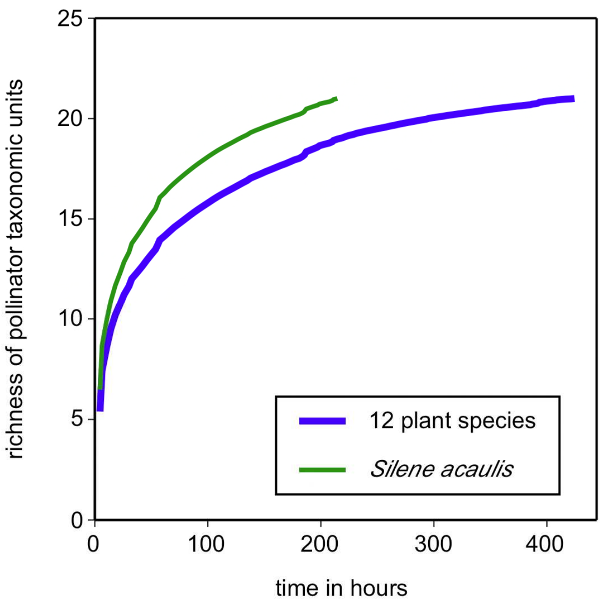

FIGURE 1. Rarefaction curves showing the cumulative sampling effort in hours and number of unique recognizable taxonomic units (number of clearly identifiable pollinator groups from the videos) for alpine pollinators. These data were derived from recordings of target plants in the alpine in 2010. Curves were calculated using EstimateS with the MaoTau metric.

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