Journal of Environmental Management 193 (2017) 64–69

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

A comparison of the effectiveness and time efficiency of traditional and photographic environmental monitoring techniques

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ARTICLE INFO

Article history:
Received 24 February 2016
Received in revised form
15 January 2017
Accepted 21 January 2017

Keywords:
Flowers
Image analysis
Cost
Environmental monitoring

ABSTRACT

Photographic methods of environmental monitoring have grown in popularity and now represent one of the main ways in which habitat and biodiversity are monitored for change through time. However, efficacy and efficiency of this technique compared with traditional approaches to environmental monitoring (direct count or observation) are lacking. This study compares the results and time-efficiency of manual versus photographic monitoring of floral abundance in low-growing flowering plants in a relatively open herbfield. Specifically, we compared 1) manual flower counting of individual plants for four species, followed by data entry in the laboratory, with 2) taking photographic images of each plant and quantifying flower counts in the laboratory. Photographic monitoring underestimated flower counts by an average of 7.5%. Manual counting was more time consuming in the field, but less time consuming in post-processing than photographic monitoring. Overall, photographic monitoring took almost twice as long as manual counting (81.5% longer in duration), which was attributed to the much longer post-processing associated with photographic monitoring. This suggests that perhaps the main benefit of photographic monitoring is a permanent record of the sampling frame rather than any cost savings or enhanced data accuracy, at least in the systems investigated in this study.

1. Introduction

Photographic monitoring has emerged as a preeminent method of environmental monitoring, offering a cost-effective method which lends itself to support by citizen-scientists (Steele and Harrow, 2014). Photographic monitoring is defined here as any operator-triggered, ground-based image which aims to quantify aspects of the natural world. Thus, the definition employed here excludes wildlife cameras which are triggered using motion or heat sensors, and have specialised application (Dixon et al., 2009), remote sensing and fixed-point automated time-lapse photography and videography (e.g. Smith et al., 1993; Reif and Tornberg, 2006). While photographic monitoring has been used for decades, the recent emergence of digital cameras (including those in portable devices), has increased the feasibility and decreased the cost of such monitoring. Photographic monitoring has been used to record changes in, for example, vegetation (McDougald et al., 1990; Elzinga et al., 1998; Fensham and Fairfax, 2002; Pickard, 2002), ice (Smith et al., 2003), coral reefs (Xi-Feng et al., 2008) and mussel beds (Witman, 1985).

While there has been a prevalence of user guides describing how photographic monitoring should be implemented (e.g. New South Wales Government 2009), critical evaluations of the technique are lacking. A prevalent perception among researchers involved in environmental monitoring is that photographic monitoring is less costly and more accurate than traditional methods (i.e. those which do not involve cameras: Hall, 2001; Nyssen et al., 2007, 2010). However, to our knowledge no comparison has been made between traditional and photographic monitoring methods, in terms of their efficacy or time-efficiency (time being the greatest component of cost).

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http://dx.doi.org/10.1016/j.jenvman.2017.01.050
0301-4797/

This study tests the efficacy and time efficiency of photographic environmental monitoring compared with non-photographic techniques. We choose a simple system in which to compare techniques, the counting of flowers on small, ground plants using both photographic and non-photographic methods. Such data could conceivably be used, for example, to establish phenology (and quantify any spatial or inter-annual phenological variations) and is collected using either photographic or traditional approaches (e.g. Crimmins and Crimmins, 2008; Inouye, 2008; Sonnentag et al., 2012). For example, semi-permanent cameras mounted in front of individual plants of interest have been used to take images at high frequencies to obtain very accurate estimates of key phenologic events in plants (e.g. first leaf appearance) and to estimate floral counts using image processing software and algorithms (Crimmins and Crimmins, 2008). However, although the potential advantages of photographic monitoring are well-established (e.g. providing permanent records, reducing observer bias), studies directly comparing photographic techniques with traditional methods in floral monitoring are lacking. Such studies would provide important information on the relative accuracy of each technique and allow the identification of specific steps in data collection where time efficiency may differ between the techniques. Researchers will then be able to make informed decisions on which technique is more appropriate for their specific research question.

This study focuses on four common plant species and quantify floral abundance for each species using both photographic and non-photographic methods. We then use these data to compare the estimates of floral abundance using each method (i.e. accuracy), as well as the time taken to complete each method, both in the field and back in the laboratory. Differences in accuracy and time efficiency of each technique in relation to differences in flower size and abundance across the four plant species are discussed.

2. Materials and methods

Images for flower counts were taken between December 2008 and January 2009 from three coastal sites (the Bluff, Barwon Heads, 38° 17′ 24″S, 144° 29′ 58″E; Thompson Creek, Breamlea, 38° 18′ 01″S, 144° 22′ 35″E; Altona Coastal Park, 37° 51′ 33″S, 144° 51′ 49″E) and one suburban area (Burwood East, 37° 50′ 49″S, 145° 06′ 42″E) in Victoria, Australia. We selected four low-growing coastal plant species which could conceivably be the target of monitoring. These species were chosen due to their abundance at each site, allowing robust sample sizes to be collected, and due to the high variability in flower sizes between species, which allowed us to make inferences which would hold across a range of flower sizes. Images were collected of one species per site consisting of cat's ear *Hypochaeris radicata* (Burwood East), cushion bush *Calocephalus brownii* (Barwon Heads), pigface *Carpobrotus rossii* (Altona) and southern sea-heath *Frankenia pauciflora* (Breamlea). Cat's ear is a small perennial herb native to Europe which has been introduced to several regions globally where it is often a noxious weed (Ortiz et al., 2008). It bears yellow flowers on erect stems up to 20 cm in height (Lamp and Collet, 1983). Cushion bush is a densely tangled round shrub growing to 2 m in height, with small globular clusters of pale yellow flowers (Bull, 2014). Pigface is a prostrate succulent perennial growing to 3 m in width, with light purple flowers (Bull, 2014). Finally, sea-heath is a spreading shrub growing to 30 cm in height with masses of small, pink flowers (Bull, 2014).

2.1. The manual count method

Many studies employ the use of direct observer counts of flowers in quadrats (e.g., Inouye, 2008). The first step in the manual count method was to select a 1 m^2 plot at random, repeating this process a total of 50 times for each site (totalling 200 plots). Each plot was then used to generate data for both the manual count method and the photographic process method. With the aid of a volunteer, total times and total flower counts were recorded for every plot. One observer (RSM) conducted all flower counts used in this study. Timing commenced from the first flower counted and concluded when all flowers within the plot had been counted (Manual Count Time; MCT). The second step in the manual count method was to enter data into a spreadsheet. This process was timed for every individual plot and was labelled as the Manual End Process Time (MEPT). A total Manual Time (MT) was then calculated (MCT + MEPT) for every plot.

2.2. The photographic process

Plants were photographed within the same 1 m^2 quadrat used for the manual count method. Fifty images per plant species (one image per quadrat) were taken with the same digital camera by RSM (Canon IXUS 860IS, 8 Mega Pixel; ISO 80, 4.6 mm lens aspect ratio and exposure set according to the lighting conditions, automatic focussing). Images were subsequently processed and analysed using Adobe Photoshop CS3. The Photographic Sequence Process involved a four step method replicated for each plot. Steps in the Photographic Sequence Process were:

1. Camera was set to the off position and held down the side of the body of the photographer with index finger resting on the 'On' button. Timing commenced when the photographer indicated that they were ready to commence the sequence.
2. Camera was turned on in the same action as positioning the camera to take the photograph of the quadrat and area within.
3. Camera was focused and photograph was taken.
4. After the photograph was acquired the camera immediately switched to the review image function allowing the photographer to quickly analyse the quality of the image. Once photographer was satisfied with the quality of the image they immediately told the timer to stop.

Following the downloading procedure, we analysed each plot and counted the total number of flowers visible in the image (downloading time was omitted, as digital connectivity means that future programs are unlikely to involve dedicated download procedures; e.g. Graham et al., 2010). The Photographic Analysis Time (PAT) commenced when the file was located and opened in Adobe Photoshop CS3 (Adobe Systems, 2007) and concluded when all flowers in the image were counted. Plant species with small flowers required time to zoom into the appropriate scale to accurately count the flowers in the image. A total Photographic End Process Time (PEPT) was then calculated for every plot, which comprised the time taken to enter the data into a spreadsheet.

Finally, to document flower size differences between the four species, which could influence their detectability, we measured the diameter of one randomly-selected flower for 20 individual plants per species. Flower diameter was measured from the images to the nearest millimetre using the software On-Site Photo 2010 (Maxmess-software, 2010).

2.3. Statistical analysis

We first tested whether flower counts based on photographic methods were correlated with counts based on manual methods. As flower counts of all species grouped followed a Poisson distribution, we conducted a Spearman rank correlation. Using generalised linear mixed models (GLMMs: see below), we then tested whether flower counts differed between the two methods to test