3D Imaging as a Method of Measuring Serotiny

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Research Article

Keywords: Pyriscence, Serotiny, Photogrammetry

Posted Date: November 13th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3570553/v1

Version of Record: A version of this preprint was published at Fire Ecology on July 22nd, 2024. See the published version at https://doi.org/10.1186/s42408-024-00300-z.

3D Imaging as a Method of Measuring Serotiny

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Abstract

<u>Background</u>:

Serotiny refers to delayed seed dissemination within plants. Serotiny, or pyriscence, plays an important role in species' reaction to fire thus accurately understanding the variation of adaptations falling under the umbrella term of serotiny is crucial to predicting the ecosystems reaction to changing fire regimes. Due to the irregular shape of cones, surface area measurement is problematic. Past studies have relied on visual estimation to determine the openness of cones or to identify when cones become open. Subjective assessments of cone opening potentially could be subject to measurement errors. In this study I demonstrate the effectiveness of 3D modeling using a readily available phone camera to quantify differences in surface area of cones before and after heating treatments. I demonstrate this method by comparing two serotinous conifer species, Monterey cypress (*Hesperocyparis macrocarpa*) and Bishop pine (*Pinus muricata*).

<u>Results:</u>

Bishop pine had an average surface area increase of 175.7% while Monterey cypress had an average surface area increase of 43.5%. Paired t-tests showed that surface area significantly increased following heating for both species.

<u>Conclusions:</u>

Bishop pine showed a much greater surface area change relative to Monterey cypress. 3D imaging with Polycam proved to be a successful method of quantifying cone opening, creating a mesh that could be measured with Blender. Using a readily available phone camera, one can create an accurate 3D model to measure changes in surface area of cones before and after fire. Further experimentation using this method could include comparisons between serotinous species, facultative serotinous species, as well as non-serotinous species. Simple methods for quantifying serotiny, such as demonstrated here, allows for improved understanding and predictions of how species respond to fire and other environmental triggers. This method of quantifying the reactiveness of species' cone opening to heat requires further investigation but holds promise in further defining the role in which fire plays in seed dispersal due to cone opening.

Key words

- Pyriscence
- Serotiny
- Photogrammetry

Introduction

Serotiny refers to delayed seed dissemination within plants. Fire is the most common trigger of serotinous seed dispersal and so the word serotiny is often used interchangeably with the word pyriscence (Nathan et al. 1999). Serotiny plays an important role in species' reaction to fire and the effect fire has with some serotinous species that are the foundation of ecosystems (Parchman et al. 2012). Thus accurately understanding the variation of adaptations falling under the umbrella term of serotiny is crucial to predicting the ecosystems reaction to changing fire regimes. Fire triggered serotiny, or pyriscence, is widely accepted as a fire-adapted trait in which seeds are able to be released as a result of a fire in woody plants. This ensures adequate seed availability post-fire and acts as an essential part in some species' reproduction (Lamont 2021). During this process fire melts syrupy resins that hold the cone scales together and the scales open away from the cone. This reaction is driven by a difference in moisture between scale tissues and the ambient air (Nathan et al. 1999). Pyriscence is often thought of as a one gene, two-allele dependent inherited trait, however this is an oversimplified assumption, as evidence suggests that it is a polygenic trait (Parchman et al. 2012). Different factors contribute to the degree of serotiny a species has, or how reactive a species is to fire as a trigger for cone opening. Pyriscence is a fire adaptation therefore fire frequency affects the differences in populations and species (Goubitz et al. 2002). This adaptation varies greatly between species, populations, individuals, and even cones on a single individual (Goubitz et al. 2002; Moya et al. 2008). However, the measurement of cone opening and what point a cone is considered open has proven difficult, limiting our understanding of this important process.

The irregular shape of cones complicates the measurement of surface area. Past studies have relied on visual estimation to determine the openness of cones or to identify when cones become open. For example, Madrigal et al. (2021) used visual estimates to define the point of opening of the first scale during heating treatments. Perry et al. (1977) used visual identification of a break in the bonds of scales or a completely open cone in heating trials of lodgepole pine. Pelletier et al. (2023) visually assessed the level of serotiny by the abundance of open scales on cones, expressed as a percentage. Habrouk et al. (1999) used a visual determination of closed versus open cones to differences in cone opening pattern. Tapias et al. (2001) visually assessed whether cones were open or closed after different heat exposures. Reyes et al. (2002) manually counted scales considered open through visual verification to show differences in opening rates in different species. Subjective assessments of cone opening potentially could be subject to measurement errors.

The study of serotiny could be improved with a reliable, objective system to measure the opening of cones. In this study I demonstrate the effectiveness of 3D modeling using a readily available phone camera to quantify differences in surface area of cones before and after heating treatments. I demonstrate this method using two serotinous conifer species, Monterey cypress (*Hesperocyparis macrocarpa*) and Bishop pine (*Pinus muricata*).

Methods

Twenty-eight Monterey cypress cones and thirty Bishop pine cones were collected from single individuals from low branches in coastal northern California. Cones were subjected to 2.5 hours at 100℉ (~38℃) within a drying oven. Before and after the heating each cone was scanned using Polycam (https://poly.cam/) (Inal et al. 2023) on an iPhone 12 pro to create a 3D mesh. During experimentation, 2 Monterey cypress cones were disregarded due to opening while in storage before the samples could be heated. Each mesh of Bishop pine cones was composed of 100 photos and each mesh of Monterey cones were composed of 60 photos (Figure 1). These were taken on Photo-mode on Polycam and processed with medium detail and object masking. Each mesh took about 1-2 minutes to capture. Time for uploading differed due to varying internet speeds. I enforced consistent scaling via the Polycam rescaling feature.

After generating the meshes, Blender (https://www.blender.org/) was used to clean the meshes and measure surface area (Figure 2). From these measurements I determined the absolute and percent change in cone surface area following the heating treatments. I used a paired t-test to determine the statistical significance of the changes in surface area.

Results

The cones of Bishop pine had an average starting surface area of 0.0115 m^2 and post-heating average surface area of 0.0317 m^2 (Figure 3) resulting in a 175.7% increase. Monterey cypress had an average starting surface area of 0.0023 m^2 and post-heating surface area of 0.0030 m^2 (Figure 3) resulting in a 43.5% increase. Paired t-tests showed that surface area significantly increased following heating for both species (Bishop pine, $t=-9.960$, $n=30$, $df=29$, $p<0.0001$; Monterey cypress, $t=-5.520$, $n=28$, $df=27$, $p<0.0001$).

Discussion

Presumably a cone that is more reactive to fire allows for wider opening and thus a higher probability of seed dispersal. More research on the effect of degree of openness on seed release should be completed to more accurately understand this relationship. Bishop pine was extremely responsive to the heating treatment, showing a much greater surface area change relative to Monterey cypress. The percent change of Bishop pine was 4 times that of Monterey cypress. Monterey cypress seems to be reactive to air drying as opposed to heating with 2 samples needing to be disregarded due to opening while in storage before the samples could be heated. This points to Monterey cypress possibly being an example of xeriscence, a term defined as, "seed release induced primarily by drying conditions that are not generated by fire (e.g. dry weather spells),"(Nathan et al. 1999). Alternatively, Monterey cypress could be an example of partial serotiny or bradychory, which is defined as, "an effect of fire or dry conditions, induces a strategic reserve of mature seeds in persistent closed cones to be retained in the canopy"(Moya 2008). This is evidence that Bishop pine is more receptive to fire triggered cone opening compared to Monterey Cypress. It is important to note that Bishop pine cones are much larger than Monterey Cypress cones. This might result in Bishop pine cones needing to be more open to release seeds as opposed to the smaller Monterey Cypress cones. There may not be a strong selective advantage for opening scales wider for smaller cones due to smaller seeds. There are also different opening types within the two species, Monterey cypress creates space between the scales while Bishop pine scales reflex away from the axis of the cone (depicted in Figure 1 and 2).

3D imaging with Polycam proved to be a successful method of quantifying cone opening, creating a mesh that could be measured with Blender. Using a readily available phone camera, one can create an accurate 3D model to measure changes in surface area of cones before and after fire. Further experimentation using this method could include comparisons between serotinous species, facultative serotinous species, as well as non-serotinous species. Simple methods for quantifying serotiny, such as demonstrated here, allows for improved understanding and predictions of how species respond to fire and other environmental triggers. This method of quantifying the reactiveness of species' cone opening to heat requires further investigation but holds promise in further defining the role in which fire plays in seed dispersal due to cone opening.

Declarations

- Ethics approval and consent to participate

  Not applicable

- Consent for publication

  Not applicable

- Availability of data and materials

  Data will be made available upon publication.

- Competing interests

  Not applicable

- Funding

  Not applicable

- Authors' contributions

  Not applicable

- Acknowledgments

  Many thanks to Jeff Kane and Lucy Kerhoulas for their advice in the process of writing. As well as Phil van Mantgem for his incredible guidance over the entire duration of crafting this paper. The manuscript was improved by the helpful comments of Liz van Mantgem and Steven Hoffman.

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Figure 1:

Figure 1A

Figure 1B

Polycam meshes before and after heating treatments for Bishop pine (A) and Monterey Pine (B).

Figure 2:

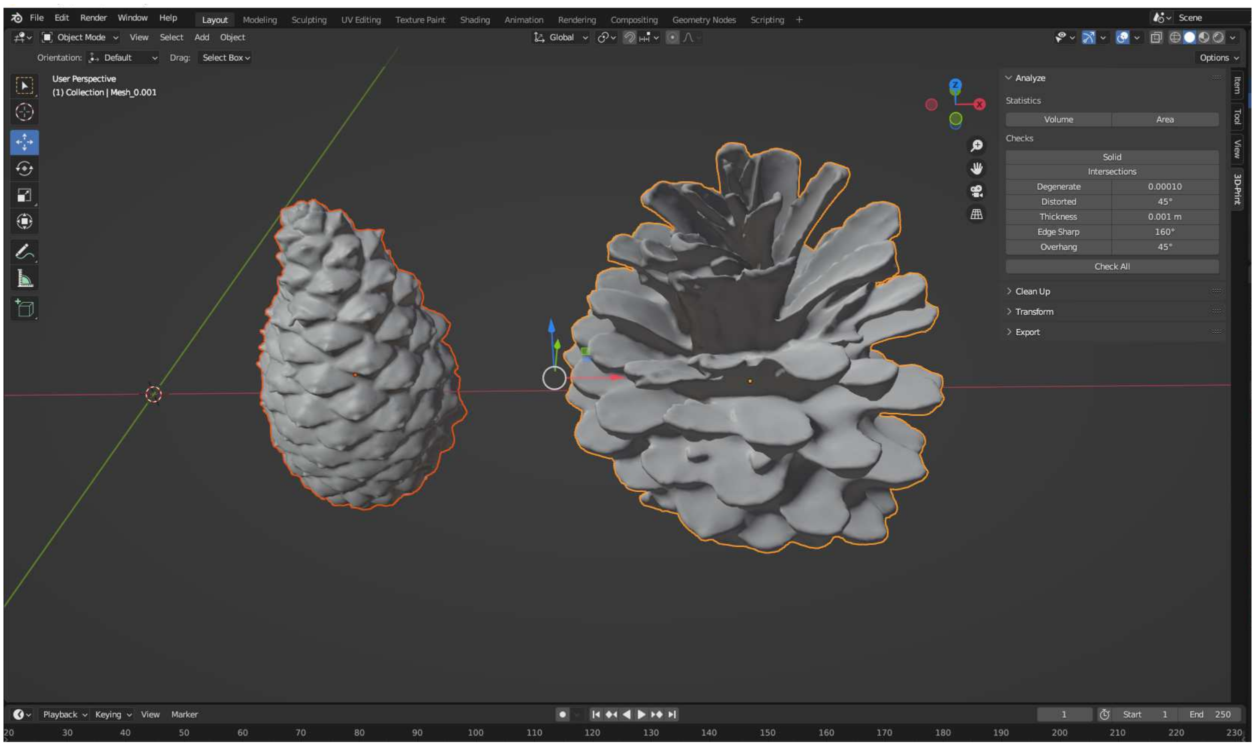


Figure 2A

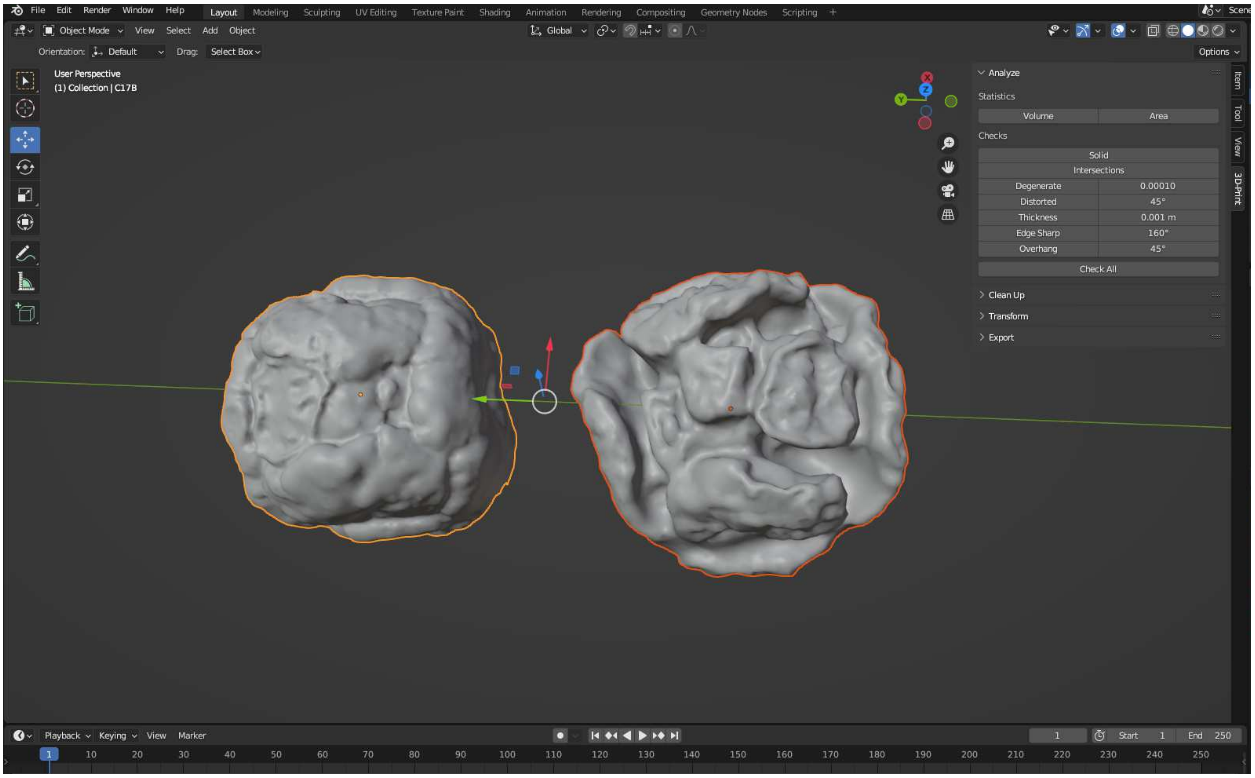
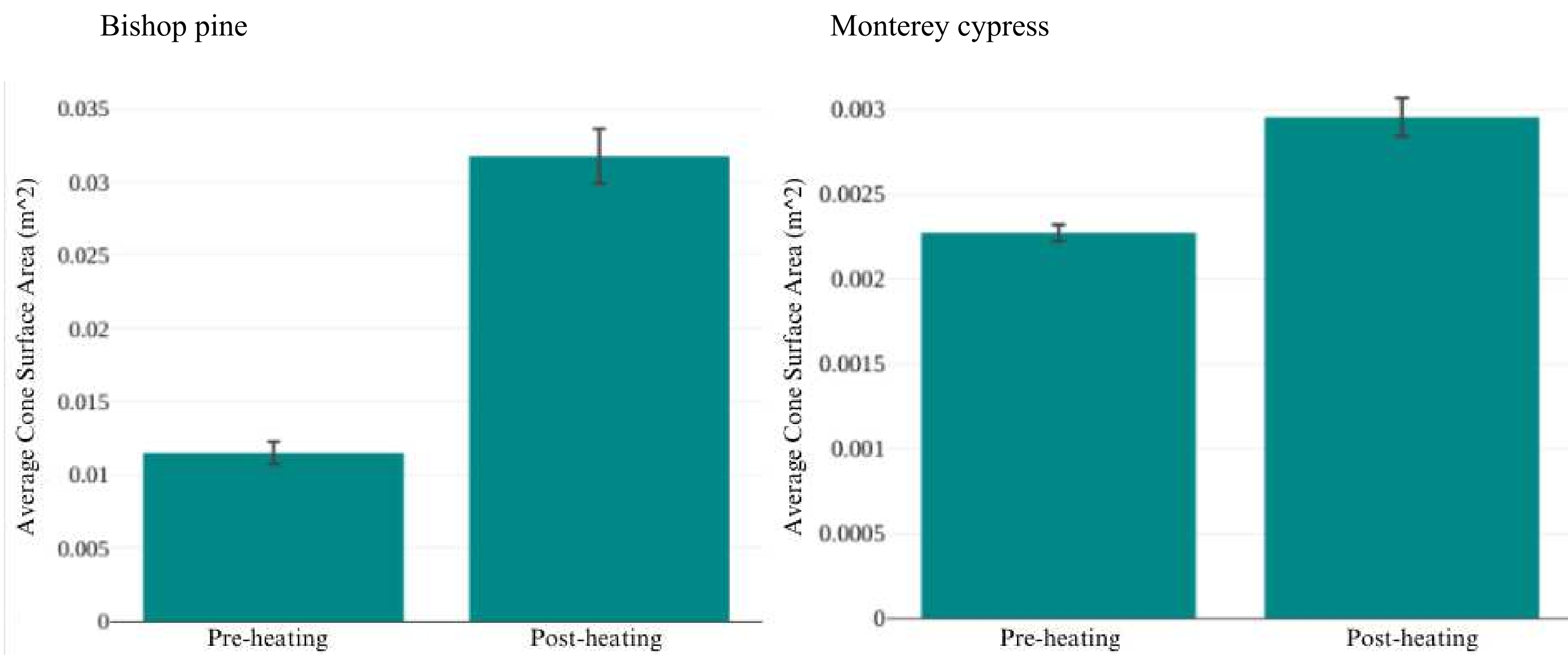


Figure 2B

Blender files before and after heating of a Bishop pine cone (A) and a Monterey cypress cone (B).

Figure 3:



The Effect of Heat Exposure on Surface Area in Bishop pine and Monterey cypress cones. Note differing y-axis scales between the two figures.