Digital 3D weed models - an innovative identification tool for early detection.

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Summary In a world-first initiative, NSW Department of Primary Industries (DPI) has developed a comprehensive and accessible tool that assists users to identify weeds that pose the highest risk to NSW. Interactive digital three-dimensional (3D) models of weed species that are prohibited in NSW due to the risk they pose, and some animal species, have been produced by scientific artists using digital 3D modelling and texturing software. These models, which form an integral component of biosecurity field personnel training, have been rated by learners as highly useful.

Keywords Prohibited matter, biosecurity, weeds, plant identification, weed officers, digital 3D, enabling tools, technology, Blender, Adobe Substance 3D Painter, Adobe Photoshop, Sketchfab.

INTRODUCTION

In contemporary biosecurity management, government investment is targeted toward prevention and early eradication activities that provide the greatest return on investment (NSW DPI 2018). Eradication programs are more likely to be successful when early detection of new incursions occurs. Early detection is only possible if biosecurity field personnel are trained to identify species that do not, or rarely, occur in their state or country. Unfortunately, restricted access to live specimens and the fragmentation of alternate resources such as photos, botanical line drawings, and textual descriptions can limit training opportunities and outcomes.

To address these barriers NSW DPI has developed a comprehensive and accessible tool in the form of realistic interactive digital 3D models of the highest risk weed, and animal species. Scientific artists have produced these models using digital 3D modelling and texturing software. The models are accurate to 1 mm. Entire species or parts of species are depicted including all diagnostic features.

To maximise early detection of high-risk weed species NSW DPI has designed and implemented a training program for NSW biosecurity field personnel which utilise the digital 3D models.

BACKGROUND

Regulation of Prohibited Matter, NSW Schedule 2 of the NSW *Biosecurity Act (2015*) lists 28 entries of terrestrial and freshwater weeds as prohibited matter in the state. These plants are identified as posing the highest risk of adversely impacting the economy, environment, and people of NSW. These species (and any of their parts) are not to be imported, kept, grown, moved, sold or dealt with in any other way. Of the 28 entries in the schedule: three of the species are not known to be found in Australia; one species was previously found in Australia and was eradicated; and seven of the species are present in NSW and under active eradication programs. The remainder are present, or have previously been present, in other states and territories.

Local government is responsible for weed control functions in NSW under the NSW *Biosecurity Act 2015* (s370). Councils and county councils appoint authorised officers to prevent, eliminate, minimise and manage weed biosecurity risks on their behalf. These authorised officers are referred to broadly as weeds officers. There are approximately 180 authorised officers appointed under the NSW *Biosecurity Act 2015* across NSW.

In a training needs survey of weeds officers at the NSW Weeds Conference held in Newcastle and online in 2019, 94% of respondents stated they wanted training on prohibited matter.

Digital 3D models in education Observing and interacting with live specimens is generally accepted to be the best way to gain plant identification skills that are transferable to field work. Due to the biosecurity risk associated with prohibited matter plants, including importing them and transporting them around the state, it was determined that the use of live specimens was not appropriate.

The most used alternative is photographs, which are an essential tool for visualising the habitat and habit of plants. But when photographs are used to identify other diagnostic features, it can lead to confusion due to multiple factors including, variable lighting, complex and competing backgrounds, poor focus and narrow depth of field. Botanical illustration is an

historically established method for the comprehensible depiction of plants that benefits from the skill of the illustrator to simplify extraneous detail and highlight diagnostic features (Hickman *et al*. 2017). While illustrations are still used in many botanical contexts, their use for people who have not been trained in the visual language of botanical illustration may be challenging. Also, understanding a 3D object (a plant) from 2D resources is inherently difficult.

Other biological fields, such as medicine, face similar issues when educating students. Access to cadavers is considered the best method for gaining an accurate understanding of human anatomy but issues exist with access and cost (Triepels *et al* 2020). Therefore, new technologies are being embraced and tested. Studies show that the use of digital 3D models in human anatomy education is an effective method for improving student understanding (Triepels *et al* 2020; Yammine and Violato 2015). The use of digital 3D models compared to traditional resources result in greater objective and subjective spatial understanding, memory retention, and identification of critical features, plus an increase in the motivation and interest of students to engage (Triepels *et al* 2020).

The use of digital 3D visualisation in botanical identification is in its infancy. This project represents a test case for the usefulness of this technology in botanical education and species identification.

Model making process Scientific artists with tertiary training in botany and scientific illustration have produced the weed models discussed in this paper. The models are created using several digital 3D modelling and texturing programs; Blender, Adobe Substance 3D Painter, Adobe Photoshop, and Sketchfab. The plant species are modelled by hand, rather than laser scanned or produced by photogrammetry as is common with non-biological digital 3D model making. The trained scientific artists possess subtle skills that are better suited to accurately represent the complexity and delicacy of plants in an economical, timely, and aesthetically engaging fashion.

The production of the model begins with understanding each species, ideally by viewing a live specimen. When live specimens are unavailable, photographs are utilised in conjunction with written botanical descriptions and botanical line drawings, when available. All parts of the plant are modelled to scale in Blender using a mesh of digital polygons. Each part of the plant is accurate to one millimetre. Accuracy is achieved with Blender's in-built scale feature and bespoke rulers created by the artists. The plant parts are positioned accurately to describe the habit of the species. Colour and texture details, including venation, hairs, lenticels, glossiness or roughness etc., are added by painting in Adobe Substance 3D Painter and through the use of some photographic textures in Adobe Photoshop. Lifelike lighting of the model environment enables realistic visualisation of the glossiness and opacity of the plant surfaces giving further diagnostic information.

The draft models are assessed by NSW and interstate biosecurity experts with first-hand knowledge of each species. Recommended changes are incorporated into the final models which are uploaded to the interactive online platform Sketchfab.

Within Sketchfab the user can move the models in 'space' to view from 360 degrees and zoom into key features. This presents a realistic sense of the size and position of the features relative to the whole. Independent scale indicators (rulers or scale bars) are included in the final models. The diagnostic features of each species are further highlighted on the models through written annotations.

Weed officer training In 2022 NSW DPI have commenced 14 'Getting to know Prohibited Matter' training sessions for weeds officers. The digital 3D weed models form an interactive component of this training alongside other training tools, such as look-alike species, physical models, and access to a range of species-specific information (e.g. WeedWise species' descriptions).

The annotation function in Sketchfab is used as one learning activity where learners complete blank annotations, enabling greater retention of what they see as the key diagnostic features of each species. Many weeds officers already have a sound understanding of botany and plant features so the training has been designed to be somewhat self-directed.

An additional 12 models have been created for incorporation into NSW DPI's established Water Weeds training package.

Table 1. Weed species modeled

Scientific name	Common name
Alternanthera philoxeroides	Alligator weed
**Andropogon gayanus*	Gamba grass

**Annona glabra*	Pond apple
**Asparagus declinatus*	Bridal veil creeper
**Bassia scoparia*	Kochia
Cabomba caroliniana	Cabomba
**Centaurea stoebe* subsp. *micranthos*	Spotted knapweed
**Centaurea X moncktonii*	Black knapweed
**Chromolaena odorata*	Siam weed
**Clidemia hirta*	Koster's curse
**Cryptostegia grandiflora*	Rubber vine
Eichhornia crassipes	Water hyacinth
**Eichhornia azurea*	Anchored water hyacinth
Egeria densa	Leafy elodea
Equisetum arvense	Horsetails
Gymnocoronis spilanthoides	Senegal tea plant
Heteranthera reniformis	Kidney-leaf mud plantain
**Hydrocotyle ranunculoides*	Hydrocotyl
Hygrophila costata	Hygrophila
**Lagarosiphon major*	Lagarosiphon
**Limnobium laevigatum*	Frogbit
**Limnobium spongia*	Spongeplant
**Limnocharis flava*	Yellow burrhead
Ludwigia longifolia	Long-leaf willow primrose
Ludwigia peruviana	Ludwigia
**Miconia calvescens*	Miconia
**Mikania micrantha*	Mikania vine
**Mimosa pigra*	Mimosa
**Myriophyllum spicatum*	Eurasian water milfoil
**Nassella tenuissima*	Mexican feather grass
Orobanche minor	Common Broomrape
**Parthenium hysterophorus*	Parthenium
**Pilosella aurantiaca*	Orange Hawkweed
Sagittaria platyphylla	Sagittaria
Salvinia molesta	Salvinia
**Stratiotes aloides*	Water soldier
**Striga asiatica*	Witchweed
**Trapa natans*	Water caltrop
**Vachellia nilotica*	Prickly acacia
**Vachellia karroo*	Karoo acacia

* denotes prohibited matter species

DISCUSSION

Assessment The usefulness of the digital 3D weed models is being assessed in ongoing subjective surveys of the 'Getting to know Prohibited Matter' training participants. To date 58 participants have completed the training evaluation. Participants are asked to respond to the statement 'The 3D digital models helped me learn about the weeds.' 83% 'strongly agreed' and 17% 'agreed.' Feedback on the training program is generally very positive with 100% of respondents strongly agreeing or agreeing that they *"feel more confident about being able to identify prohibited matter in the field*."

Engagement with Prohibited Matter species on the NSW DPI WeedWise website has increased since the addition of the digital 3D models. Over 4000 views of the Prohibited Matter 3D models were registered in the first four months of their presence on NSW WeedWise. Furthermore, activity on the DPI internal and public social media pages highlighting the presence of the 3D models on WeedWise has generated engagement with the species and very positive feedback.

Universal access to models In the spirit of national and international collaboration, the digital models are publicly available on the NSW DPI WeedWise website. This enables access to the models for weed professionals from other state agencies plus the general public. This accessibility enables greater possibility of early detection and eradication of high-risk species across Australia and the world.

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