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A review of the fire response of *Genoplesium* R. Br. *sensu lato* (Orchidaceae) and implications of fire management on habitat

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***Abstract*:** *Genoplesium* R.Br. *sensu lato* is an Orchidaceae genus of perennial geophytic herbs with up to 80 recognised species primarily distributed in eastern Australia. Species are commonly found occupying relatively open habitats, including partially cleared habitats such as track margins, powerline easements and bushfire protection zones. In the absence of fire and other disturbances, dense vegetation commonly appears to outcompete the genus. Habitat management for threatened *Genoplesium* species has involved regular slashing of habitat to control vegetation regrowth, although this management action has only been applied across relatively small areas of habitat.

Despite a lack of detailed studies on *Genoplesium* species, there is a large body of evidence from opportunistic observations and studies of related terrestrial orchid species which suggests that mature individuals of *Genoplesium* are likely to be stimulated by fire during their dormancy periods. Observed increases in the size of monitored populations in the season immediately after fire indicates that members of the genus may be dormant, or at least undetectable, in unburnt habitat until fire or similar disturbance triggers increased flowering. The exclusion of fire from habitat is likely to result in reduced flowering, and recruitment, and ultimately may cause localised extinctions.

The fire histories of two short range endemic species *Genoplesium insigne* and *Genoplesium branwhiteorum* on the NSW Central Coast provide a case study.

Detailed field studies for many rare *Genoplesium* species including targeted post-fire surveys are required to confirm their fire responses, and to improve understanding of their potential to remain dormant in unburnt habitat, to investigate the impact of fire exclusion and to inform conservation assessments and land management practices.

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Introduction

Genoplesium R.Br. *sensu lato* is a genus of perennial geophytic herbs with up to 80 recognised species (Copeland and Backhouse 2022). The genus is primarily distributed in southern and eastern Australia, with a single species known from New Caledonia and two species occurring in New Zealand (Jones 2001). The accepted taxonomic treatment of this genus differs between jurisdictions within Australia, see Renner et al. (2022) for a discussion of the various treatments, although for the purposes of this review the generic concepts of Clements and Jones (1989) are applied, consistent with the current position of the National Herbarium of New South Wales. *Genoplesium* is a member of the Prasophyllinae subtribe within the Orchidaceae and is distinguished by a hinged and mobile labellum, a cushion like callus on the labellum and deeply notched column wings (Jones 2001). Other characteristics of the genus include a short, fused leaf and peduncle on flowering plants with small, often dark coloured flowers, which can make detection of individuals in the field difficult.

A comparatively large proportion of *Genoplesium* species are recognised as rare or threatened with up to 18 species listed under relevant state legislation across Australia. Species of *Genoplesium* are commonly detected in areas with an open vegetation structure, having a low cover of canopy and midstorey species, such as open rock plates (Jones 2021) and areas which have been partially cleared, or thinned, such as track margins, powerline easements and bushfire protection zones (Jones et al. 1999; Bernhardt et al. 2017). In some cases, dense regrowth of native vegetation within previously open habitat has resulted in a decline in flowering and detection of rare *Genoplesium* species, a pattern observed across related terrestrial orchids in Australia (Lunt 1997) and orchid species in Europe (Köhler et al. 2023). Consequently, ongoing control of vegetation regrowth has been implemented or recommended for management of habitat for several rare *Genoplesium* species including *Genoplesium insigne* (DPE 2023a), *Genoplesium branwhiteorum* (DPE 2023b)*, Genoplesium firthii,* (DPIWE 2002), *Genoplesium brachystachyum* (TSS 2016), and *Genoplesium morrisii* (TSS 2013). This biomass control, commonly involving annual slashing of vegetation outside of the active growth season of the *Genoplesium* species, is effective for maintaining population sizes of rare *Genoplesium* species across periods of up to five years (Towle et al. 2022). However, there are limitations on the area across which this management action can be implemented, and its effectiveness appears to be dependent upon regular ongoing slashing which requires ongoing resources, funding, and landowner support. Further, the long-term implications of regular slashing are unknown, and it has been hypothesised that frequent stimulation of flowering could divert resources away from development of replacement tubers (Weston et al. 2005). Due to these limitations, there is a need for more long-term and widely applicable habitat management practices.

Fire, which has influenced the structure and composition of vegetation in Australia for millennia (Miller and Murphy 2017), may represent a more long-term and widely applicable solution to maintenance of an open habitat structure, without the regular stimulation to flower which may divert resources away from replacement tuber production. However, the response of *Genoplesium* species to fire often remain unknown or poorly understood. For example, under the NSW Bushfire Environmental Assessment Code (RFS 2021), more than half the *Genoplesium* species listed on the NSW 'Threatened Species Hazard Reduction List' (RFS 2013) have controls prohibiting fire, slashing or trittering within 100 m of the known location of the listed rare *Genoplesium* species. The aim of this review is to synthesise existing knowledge of the fire response of *Genoplesium* species to inform future research and habitat management priorities.

Accounts of the fire response of *Genoplesium* plants

There are multiple accounts of increased flowering of *Genoplesium* species in the flowering seasons after fire. A large increase in the population of *Genoplesium superbum* was reported in areas of Morton National Park following bushfire in early 2020, although large increases were also detected in unburnt populations across the same period which was attributed to increased rainfall (Canackle et al. 2020; Roper 2021). Population counts of *Genoplesium ectopum* following bushfire in January 2003 also indicated that high intensity fires are likely to have benefited the species, although the fire response was also considered to be influenced by subsequent rainfall (Frawley 2008). Large populations of *Genoplesium ruppii* and *Genoplesium fimbriatum* have been detected for the first-time following fires within Northern Sydney (APS 2016) and on the NSW Central Coast (Ecoplanning 2020). Additionally, multiple orchid field guides report that *Genoplesium* species as a whole are fire stimulated (Jones et al. 1999; Jones 2021), or identify individual species as growing, or flowering, prolifically after fire including *Genoplesium archeri*, *Genoplesium morrisii* and *Genoplesium pumilum* (Jeanes and Backhouse 2006).

While there are multiple accounts of positive responses of mature *Genoplesium* species to fire, not all reports are positive. Populations of *Genoplesium despectans* within Kinglake National Park were not seen following the Black Saturday Bushfires in Victoria in 2009 (Duncan 2012). The same species was observed flowering at pre-fire levels in Bunyip State Park following the same fire event, indicating that the response of the species varied between populations (Duncan 2012). The varied responses to fire within and between *Genoplesium* species indicates that not all fire events are equal and that many variables may influence the response. The influence of seasonality of fire on the response of *Genoplesium* species has not been studied, however it has been shown to have a large influence on the fire response of terrestrial orchid genera including *Thelymitra*, *Pterostylis* and *Glossodia* (Jasinge et al. 2018). Fires during the active growing and flowering stages of these genera were found to have a deleterious impact on studied populations, while fires during dormancy periods did not impact populations in the same way (Jasinge et al. 2018). Fire intensity may

also influence the response of *Genoplesium* species. Fire stimulated flowering has been reported from high intensity fires including the Morton National Park fires in early 2020 (Canackle et al. 2020) and low intensity prescribed burns (Ecoplanning 2020).

Post-fire rainfall has also been identified as impacting the fire response of *Genoplesium* species (Frawley 2008; Canackle et al. 2020;). However irrespective of fire, rainfall is identified as both determinant of flowering and influencing the specific timing of flowering within a season (Bower et al. 2015; Canackle et al. 2020; Roper 2021). Therefore, any stimulated flowering of *Genoplesium* from fire is likely to be dependent upon follow-up rainfall.

Fire response of seed and immature *Genoplesium*

While documented accounts of the fire response of *Genoplesium* species do not distinguish between mature and immature plants, observations of *Genoplesium* post-fire commonly refer to enhanced flowering and are therefore only observing the response of mature individuals. Detailed studies and observations of fire impacts on the immature stages of *Genoplesium* are lacking. Seeds of *Genoplesium* species, and indeed almost all orchids, are minute and dust like (Rasmussen 1995). The simple seeds of *Genoplesium* species do not possess a hardened seed coat, or other adaptations, which may protect seeds from fire. Therefore, seeds of *Genoplesium* species are almost certainly killed when exposed to the heat and steam produced by fire.

While seed exposed to fire will almost certainly be killed, seed released in a post fire environment may be positively impacted by recent fire events. In addition to increased germination rates, a range of evolutionary advantages have been hypothesised for fire stimulated flowering and seed release into post-fire environments. This includes optimal levels of resources required for both growth and reproduction of plants (water, nutrients, space, and/or light), reduced competition for these resources from fire-killed species, reduced risk of reproductive failure from further fires, and more effective wind dispersal as the surrounding vegetation has yet to close over again (Lamont and Downes 2011).

The response to fire of protocorms and immature tubers of *Genoplesium* species also remain unstudied. However, as these life stages occur underground, the response is likely to depend upon the degree of insulation from heat provided by the substrate in which individuals are growing. There is anecdotal evidence of fire negatively impacting immature seedlings with multiple fires in quick succession having been identified as being detrimental to immature orchids germinating after the initial fire (Jones 2021).

Dormant until disturbed?

The short time-frame between fire events and observed increases in flowering of *Genoplesium* species (less than 12 months) indicates that enhanced flowering in the first season after fire is the result of mature individuals being stimulated to flower and does not represent post-fire recruitment within burnt habitat (although this may occur after fire). The time to first flowering of Australian terrestrial orchid genera including *Genoplesium*, incorporating the period from seed release through protocorm development and immature tuber stages, is reported to be in the order of 2-3 years in cultivation and approximately 4-5 years in the wild (Backhouse and Cameron 2005). Therefore, any increased recruitment following fire events is unlikely to be observed in the mature flowering population for up to three years. Increases in the size of monitored populations of *Genoplesium* species in the first seasons post-fire (Frawley 2008; Canackle et al. 2020) are most likely the result of previously undetected individuals, either due to dormancy or non-flowering, being stimulated to flower by fire. Due to the highly cryptic nature of non-flowering *Genoplesium* species, failure to detect these individuals during pre-fire monitoring projects does not necessarily indicate their absence.

The possible occurrence of dormant or non-flowering *Genoplesium* individuals within unburnt habitat has implications for the conservation and habitat management of rare species within the genus. Efforts to protect only those locations where rare *Genoplesium* species have been detected through flowering has the potential to overlook large areas of habitat with potentially large dormant populations. The period after fire or slashing where flowering is enhanced remains unknown and detailed studies are required to address this question.

Fire history of two short range endemic *Genoplesium* species on the NSW Central Coast: A case study

Two rare *Genoplesium* species, *Genoplesium insigne* and *Genoplesium branwhiteorum* (**Figure 1**), have restricted distributions within the Wyong IBRA subregion (Thackway and Cresswell 1995), on the NSW Central Coast. Known occurrences of these two species are almost entirely restricted to areas which have been partially cleared, or thinned, such as track margins and areas regularly slashed for infrastructure protection such as powerline easements and bushfire protection zones. Consequently, habitat management for these species has included ongoing control of vegetation regrowth at multiple sites which has been an effective tool at maintaining population sizes across periods of up to five years (Towle et al. 2022; DPE 2022a). Enhanced flowering of both species has been observed in the season after a bushfire conforming to the general trend in *Genoplesium* of fire-stimulated flowering and dormancy in the absence of fire.

It was therefore hypothesised that the occurrence of these species almost entirely within partially cleared habitats was a result of fire exclusion from suitable habitats and the inability to detect the species within long unburnt habitat. To investigate how the recent fire history across the region may have influenced the current pattern of occurrence of these

two species, the fire history of the Wyong IBRA sub-region (NPWS Fire History Dataset, DPE 2022b) was compared to the recommended fire intervals (Kenny et al. 2004), for Plant Community Types (PCTs) mapped across the region (DPE 2022c). PCTs present within the region, but in which the species have not been previously recorded (DPE 2022d) were excluded. The recommended fire interval for those PCTs associated with *Genoplesium insigne* and *Genoplesium branwhiteorum* ranged from five to fifty years (Kenny et al. 2004). Across the Wyong IBRA subregion, a total of 37,795 ha of habitat has been mapped as supporting PCTs with which *Genoplesium branwhiteorum* and *Genoplesium insigne* are associated (DPE 2022d; **Figure 2**). For approximately 70 % (26,366 ha) of this habitat the time since last fire exceeded the recommended maximum fire interval or no fire has been recorded. Further, in approximately 85 % (32,225 ha) of the identified habitat the time since last fire exceeded the median of the recommended fire interval. While the fire history dataset used in this analysis is unlikely to be complete, the majority of habitat for these species within their restricted distribution has remained unburnt for extended periods exceeding the maximum recommended fire interval. While this doesn't confirm that fire exclusion has caused the current pattern of known occurrence for these two rare *Genoplesium* species, it highlights the potential for fire exclusion to have caused an underestimation of areas of occupancy. Detailed field studies are required to investigate the role of fire in the life cycle of these species and its role in maintaining suitable habitat for these species.

Figure 1: ***Genoplesium insigne*** a) entire plant, b) inflorescence, and ***Genoplesium branwhiteorum*** c) entire plant, d) inflorescence

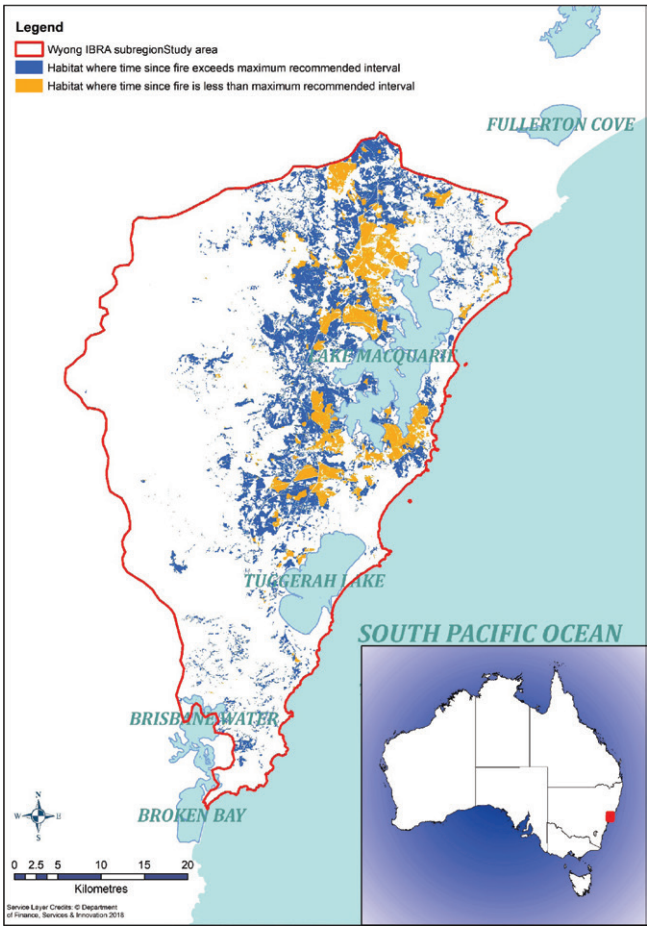

Figure 2: Habitat where time since last fire exceeds recommended fire intervals for the mapped PCT.

Conclusions

Despite the lack of detailed studies on the fire response of individual *Genoplesium* species, there is a body of evidence which suggests that fire and mechanical vegetation slashing during their dormancy periods can stimulate mature individuals of the genus to flower. However, the stimulated flowering is likely to be influenced by, or dependent upon, post-fire rainfall. The association of many *Genoplesium* species with open, slashed, or thinned habitats suggests that these species may be dependent upon fire, or other disturbance for the maintenance of suitable habitat structures. In the absence of fire, or other disturbances, these species may remain dormant, or at least undetectable. The exclusion of fire from habitat for the genus is likely to reduce flowering, seed production and recruitment and may drive population declines in some species. Implementing fire as a management tool across the habitat of rare *Genoplesium* species may reverse such declines and maintain areas of suitable habitat for these species across their range. There is a need for more detailed field studies, incorporating population monitoring before and after fire events, to confirm the hypotheses presented within this review and to investigate how individual aspects of fire which may influence the response of the genus. An improved understanding of the

role of fire in the ecology of *Genoplesium* species would better inform our understanding of the conservation status of the many rare species and land management practices for their conservation.

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