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Estimation of juvenile period in slow-maturing plants over space and time

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Background

Short fire intervals can drive declines in plant populations through immaturity risk. This can occur when the interval between two fires is shorter than the time required for a plant population to develop the capacity to persist through the second fire, typically via the accumulation of an adequate seed bank. This risk is thought to be greatest for fire-killed (obligate-seeder) species with canopy-stored (serotinous) seed banks as they lack both the ability to resprout and a residual seed bank. Recognising this issue, fire managers often seek to maintain fire intervals within an ecologically tolerable (or 'acceptable') range for a vegetation community to maximise the probability of persistence of all species.

The risk of population decline under specific fire intervals can be estimated by measuring the time after fire required by obligate-seeder species to reach reproductive maturity (the juvenile period). Juvenile periods vary across space and time, and the lack of an approach to generalise beyond case studies limits how juvenile period data can inform fire management at regional scales. This lack also constrains identification of situations where short intervals may have compromised plant persistence in the past, or where risk might change in the future with climate change - creating uncertainty over the need for conservation interventions. To address this issue, we tested how well environmental factors predicted juvenile period, hypothesising that juvenile periods would be longer in less productive locations. We used these relationships to develop spatial models of minimum tolerable fire intervals based on the projected juvenile period of slow-maturing serotinous obligate-seeder species, using various metrics of juvenile period, and applicable under recent and predicted future climates.

Modelling juvenile period from environmental predictors

We compiled juvenile period data in serotinous obligate-seeders from 24 studies across southwestern Australia. For each combination of broad vegetation type and location represented in these data, we identified the species with the longest juvenile period and derived values of environmental productivity (climate variables, for example annual precipitation and minimum and maximum temperature; remotely sensed measurement of gross primary productivity (GPP)) for these locations. We identified the best linear models of juvenile period from environmental predictors, and then projected juvenile period estimates spatially for both recent climatic conditions and future climate scenarios.

Findings

- Environmental productivity variables correlated well with juvenile period data, explaining up to 76% of the variation. Juvenile periods increased with lower annual precipitation, lower mean annual minimum temperature and lower mean annual GPP.

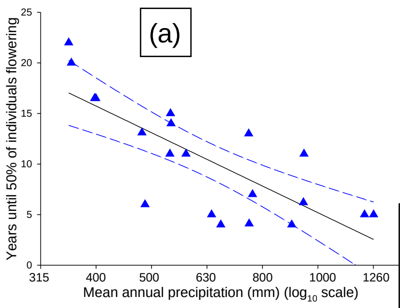

Fig. 1. (a) Relationship between annual precipitation and the juvenile period of slow-maturing serotinous obligate-seeders using years post-fire until 50% of individuals were flowering (with 95% confidence bands). Examples of vegetation types with juvenile period data range from (b) relatively moist eucalypt open forests to (c) dry mallee woodland and shrublands and (d) semi-arid eucalypt woodlands.

- Spatial projection of these relationships suggests that, under recent conditions, juvenile periods for the slowest-maturing obligate-seeders increase from the south-west to the drier east and north. Localised increases are also associated with specific landscape features such as montane sections of the Stirling Range, that, due to altitude-related lower temperatures, and landform constraints on GPP, have longer juvenile periods than surrounding areas, even though precipitation is higher.
- Future climate scenarios indicate fewer areas with shorter modelled juvenile periods, with greater lengthening of juvenile period along the southern and western coasts, further into the future, and with higher carbon emissions.

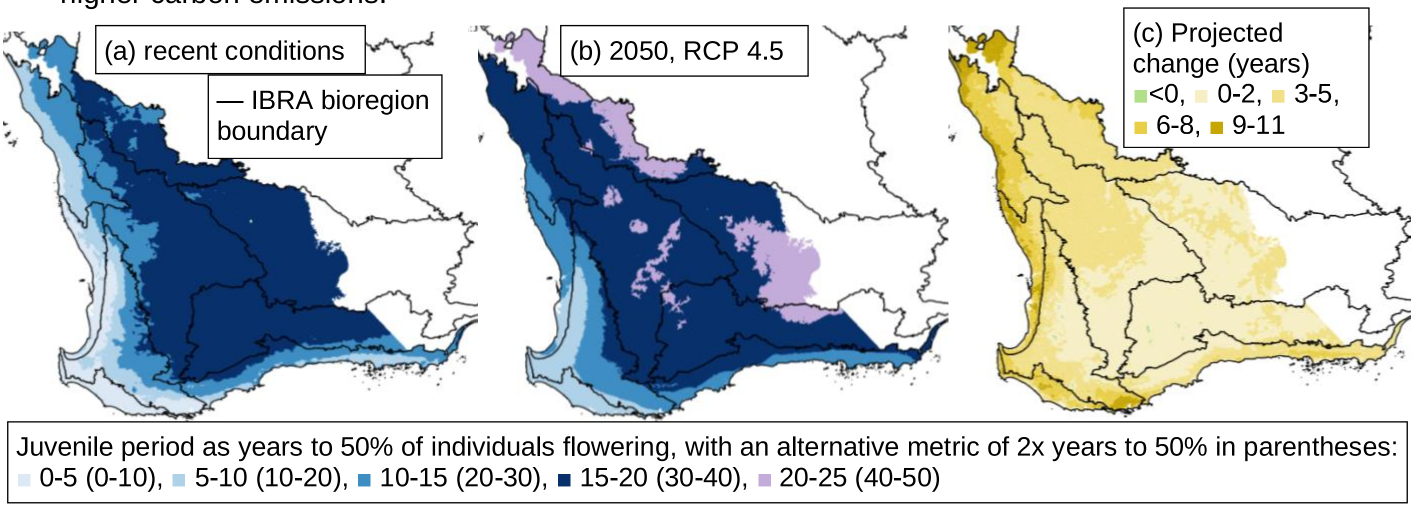

Fig. 2. Spatial projections of modelled juvenile period for slow-maturing serotinous obligate-seeders: (a) under recent conditions; (b) in 2050 under moderate emissions scenario RCP 4.5; and (c) projected change in juvenile period between recent conditions (a) and 2050 RCP 4.5 (b), based on years to 50% of individuals flowering. Juvenile period surfaces should be interpreted as showing broad-scale spatial and temporal trends, as opposed to providing specific values for specific locations. See Information and Resources for details on obtaining spatial layers (a) and (b).

Management implications

A large portion of the variability in juvenile period across southwestern Australia was explained by measures of environmental productivity, such as rainfall. Juvenile period in slow-maturing serotinous obligate-seeder species could thus be estimated across the region from environmental predictors, removing a major barrier for informed fire and conservation management. Overlaying these models with validated fire interval data and the occurrence of serotinous obligate-seeder species may help identify locations where immaturity risk impacts may have occurred, and support targeted conservation interventions. Projected climate-driven increases in juvenile period indicate high risk of short fire interval impacts under continuation of historic fire intervals. The strong anthropogenic influence on fire ignitions across southwestern Australia, combined with fuel management and fire suppression actions, suggests that fire management and planning can contribute to reducing instances of immaturity risk.

In applying juvenile period-productivity relationships to inform minimum tolerable fire intervals, it is important to recognise that the resolution of both the fire history and environmental productivity spatial layers may obscure landscape features that support the persistence of slow-maturing serotinous obligate-seeders in fire refugia. Fire refugia are locations burnt less frequently or less severely than the surrounding landscape. Some are predictable over space and time, associated with landscape features that act as barriers to fire spread, such as rock outcrops, salt lakes, riparian strips and wetlands. Other fire refugia are spatially and temporally stochastic, being influenced by the interaction of plant and community traits such as vegetation flammability, fire weather and time since fire. Stochastic refugia are more likely to function with burning under less severe fire weather and lower fuel age: conditions perhaps more likely under prescribed burning scenarios. Thus, the minimum tolerable fire interval for a species may not be same as the ideal interval between fires within a prescribed burning management unit taking those other factors, such as severity, weather, fuel loads or previous fire patchiness, into account.

Further information and resources

Gosper CR, Miller BP, Gallagher RV, Kinloch J, van Dongen R, Adams E, Barrett S, Cochrane A, Comer S, McCaw L, Miller RG, Prober SM and Yates CJ (2022) Mapping risk to plant populations from short fire intervals via relationships between maturation period and environmental productivity. *Plant Ecology* https://doi.org/10.1007/s11258-022-01229-6

Spatial layers for Fig. 2a and b will be made available through the CDDP for DBCA users (Flora/Juvenile Period) and DataWA.