Spatial variation in sensitivity of serotinuous Proteaceae to wildflower harvesting inferred from large-scale demographic data in the Cape Floristic Region

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The fire-driven life cycle of serotinous Proteaceae

Introduction and background:


Collected demographic data for 26 study species

>3400 population-level records across the CFR
Introduction and background:

Range-wide demographic variation

*considerable inter- and intraspecific variation in fecundity and recruitment

Are population growth rates always positive... everywhere?

Introduction and background:

Pagel et al. (in prep.)
Wildflower harvesting of serotinous Proteaceae in the CFR

Can large-scale demographic data be useful to conservation?

- **Aim**: to investigate the effects of harvesting (i.e. reduction of the canopy seed bank) across environmental variation on the population viability of 26 serotinous Proteaceae

  - With specific reference to the “50% harvesting rule” *universally* applied to all species (and populations)

- The effects of wildflower harvesting are currently inconclusive:
  
  i. studies using different estimates of demographic parameters, different models of population dynamics and spatial extent of investigations
  
  ii. Only 7 serotinous *Proteaceae* species partly studied to date…

  - Maze & Bond (1996): *P. repens, P. neriifolia*
  - Cabral et al. (2011): *P. repens, P. neriifolia and P. compacta*
Research approach:

**Population Viability Approach: data requirements**

- **PVA:** combine environmental- and demographic data with a population dynamic model to simulate the effects of harvesting as a proportional reduction of seeds in the canopy seed bank over time.

**Data requirements:**

- **Environmental data**
  - Climate, fire interval and soil nutrient data (*Schulze 2007; Wilson et al. 2015*)

- **Demographic data**

- **Population dynamic model**

**Simulation:**

Simulate effects of harvesting to compare two scenarios: 0% and 50%.
Prediction of demographic rates (per generation)

Statistical demographic model:
- Fecundity
- Recruitment
- Adult fire survival
- Prob. of reproductive maturity

Model assumptions:
\[ T_{\text{max}} = 100000 \text{ years} \]
\[ N(0) = 1000 \text{ plants} \]
\[ A = 10000 \text{ m}^2 \]

Local population dynamics
- Simulated per generation; length of fire interval
- Length of the next fire interval from likelihood distribution; \textit{Wilson et al. 2015}
- Site-specific environmental data (climate, fire interval and soil fertility)

Stochastic simulation model:
- Adult fire survival
- Fecundity
- Recruitment
- Seed harvest

Next time step \((g)\)

*if the local population is ‘extinct’, time to extinction (years) in response to different harvesting rates is recorded*
Research approach:

Model simulation

- Simulations for *P. repens* to wildflower harvesting
- Stochastic simulations with a random sequence of fire intervals causing fluctuations in populations size until the population goes “extinct”
Research approach:

Model simulation

- Simulations for *P. repens* to wildflower harvesting
- Stochastic simulations with a random sequence of fire intervals causing strong fluctuations in populations size until the population goes extinct

![Graph showing population size over time with symbols indicating Tm(0%) and 0% harvesting: one population & multiple replications](image)
Model simulation

Research approach:

- Simulations for *P. repens* to wildflower harvesting
- Stochastic simulations with a random sequence of fire intervals causing strong fluctuations in populations size until the population goes extinct

![Graph showing population size over time with different harvesting rates](image-url)
Research approach:

Model simulation

- Simulations for *P. repens* to wildflower harvesting
- Stochastic simulations with a random sequence of fire intervals causing strong fluctuations in populations size until the population goes extinct

Graph showing population size over time with markers for 0% and 50% harvesting.
Research approach:

Model simulations

- Simulations for *P. repens* to wildflower harvesting
- Stochastic simulations with a random sequence of fire intervals causing strong fluctuations in populations size until the population goes extinct

Grimm & Wissel (2004)

Reduction of fecundity -> reduce population size -> increase extinction risk

\[
\begin{align*}
T_m(50\%) & \quad T_m(0\%) \\
\text{Reduction of fecundity} & \quad \text{increase extinction risk}
\end{align*}
\]

\[
\begin{align*}
P_{130}(0\%) & = 0.019 \\
P_{100}(50\%) & = 0.037
\end{align*}
\]
Research approach:

Model simulations

- Simulations for *P. repens* to wildflower harvesting
- **Population 2**: higher vulnerability to 50% harvesting than population 1
Results:

Sensitivity to harvesting from simulations

Proportions of populations (%) at ‘risk’ of 50% harvesting

Protea nerifolia

RISK CATEGORIES

HIGH >>> at least 50% within 10 years or three generations

INT >>> at least 20% within 20 years or five generations

LOW >>> at least 10% within 100 years
Results:

Variation in sensitivity to harvesting

Proportions of populations (%) at ‘risk’ of 50% harvesting

Protea neriifolia = 0% at risk

Leucadendron rubrum = ~1% at risk

Protea punctata = ~12% at high risk
Results:

Variation in sensitivity to harvesting

Proportions of populations (%) at ‘risk’ of 50% harvesting (n=19)
Results:

Spatial variation in sensitivity to harvesting

Proportions of populations (%) at ‘risk’ of 50% harvesting

$L.\ rubrum$

~1%
The relationship between sensitivity to harvesting and environmental variation?

Environmental variation in sensitivity to harvesting

Results:
Spatial variation in sensitivity to 50% harvesting (n=19)
- considerable variation among and within species
- sensitivity to harvesting tends to cluster along the edge of the species’ range & environmental limits (u-shaped responses)
- climate change will likely amplify effects of harvesting (?)

Take home message: caution against the application of a general management guideline (“50% harvesting rule”) applied across different species/populations and regions

Can this type of information be used to develop locally adapted and/or species-specific harvesting regimes?
- Donut. Or do nought?: How do we apply this in the “real world”??
Demographic, functional and macroevolutionary determinants of range dynamics and large-scale ecological niches in South African Proteaceae

The team

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Introduction and background:

Spatial variation in demography

*P. punctata*

**Fecundity**
- Fire interval (a): partial $R^2 = 0.38$
- Population density: partial $R^2 = 0.07$

**Recruitment**
- Fire interval (a): partial $R^2 = 0.18$
- Soil moisture stress (% days): partial $R^2 = 0.04$