

Moderate disturbances catalyse forest transitions in the temperate-boreal ecotone

Marie-Hélène Brice

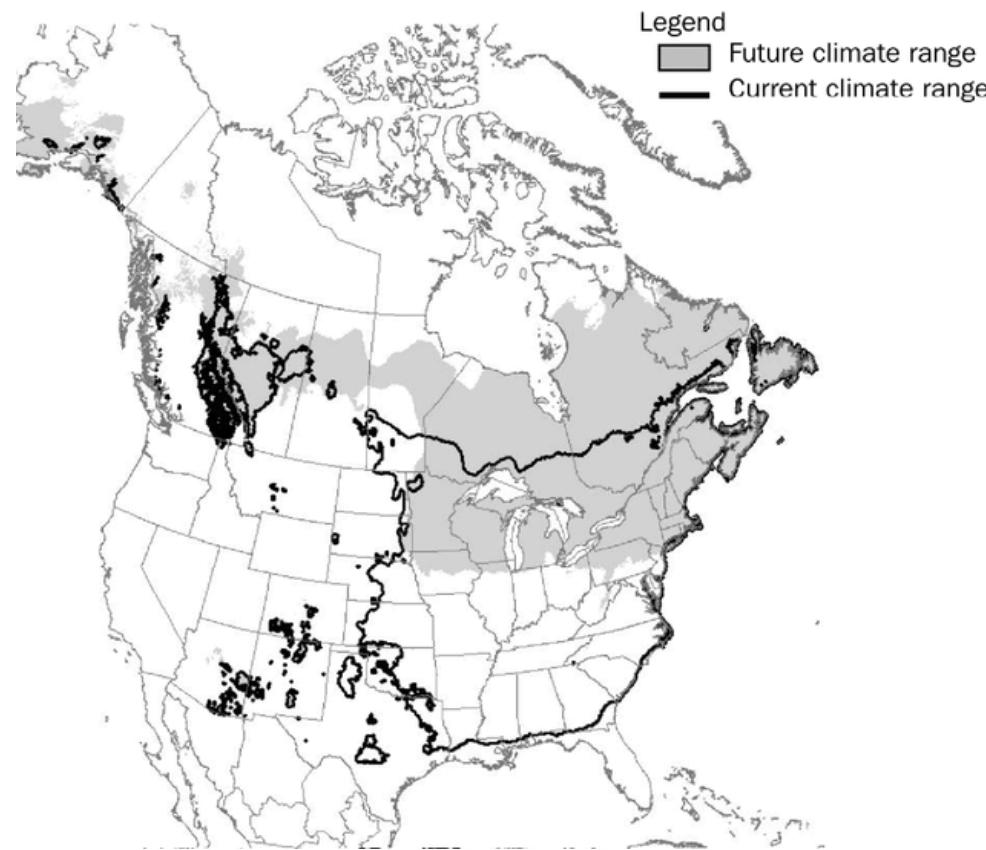
Pierre Legendre, Marie-Josée Fortin

github.com/mhBrice/talk_transition



Shift in species distribution

Future climate envelope for Sugar Maple (2071-2100)



McKenney et al. 2007. BioScience.

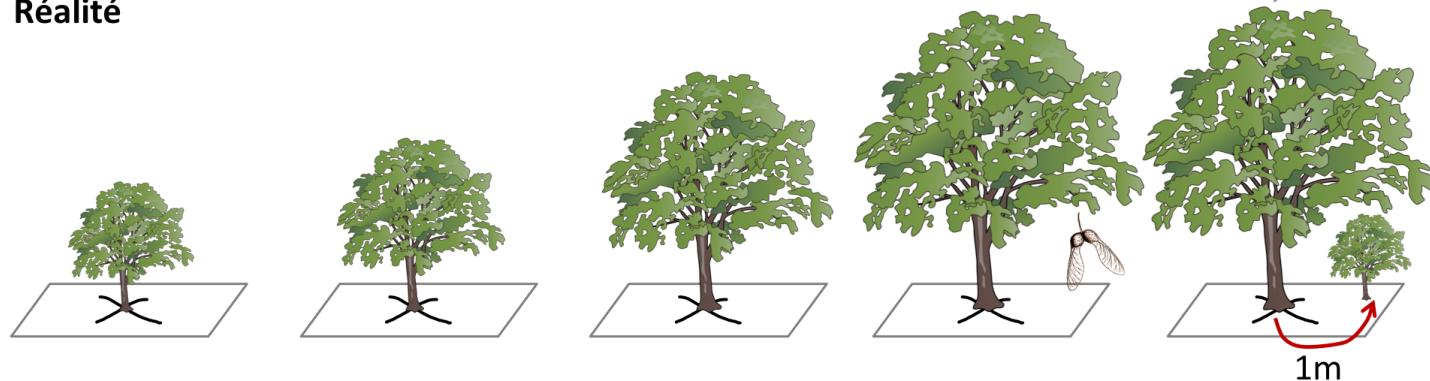
Constraints to migration

- Slow demographic rates
- Limited dispersal ability
- Soil heterogeneity
- Interspecific competition

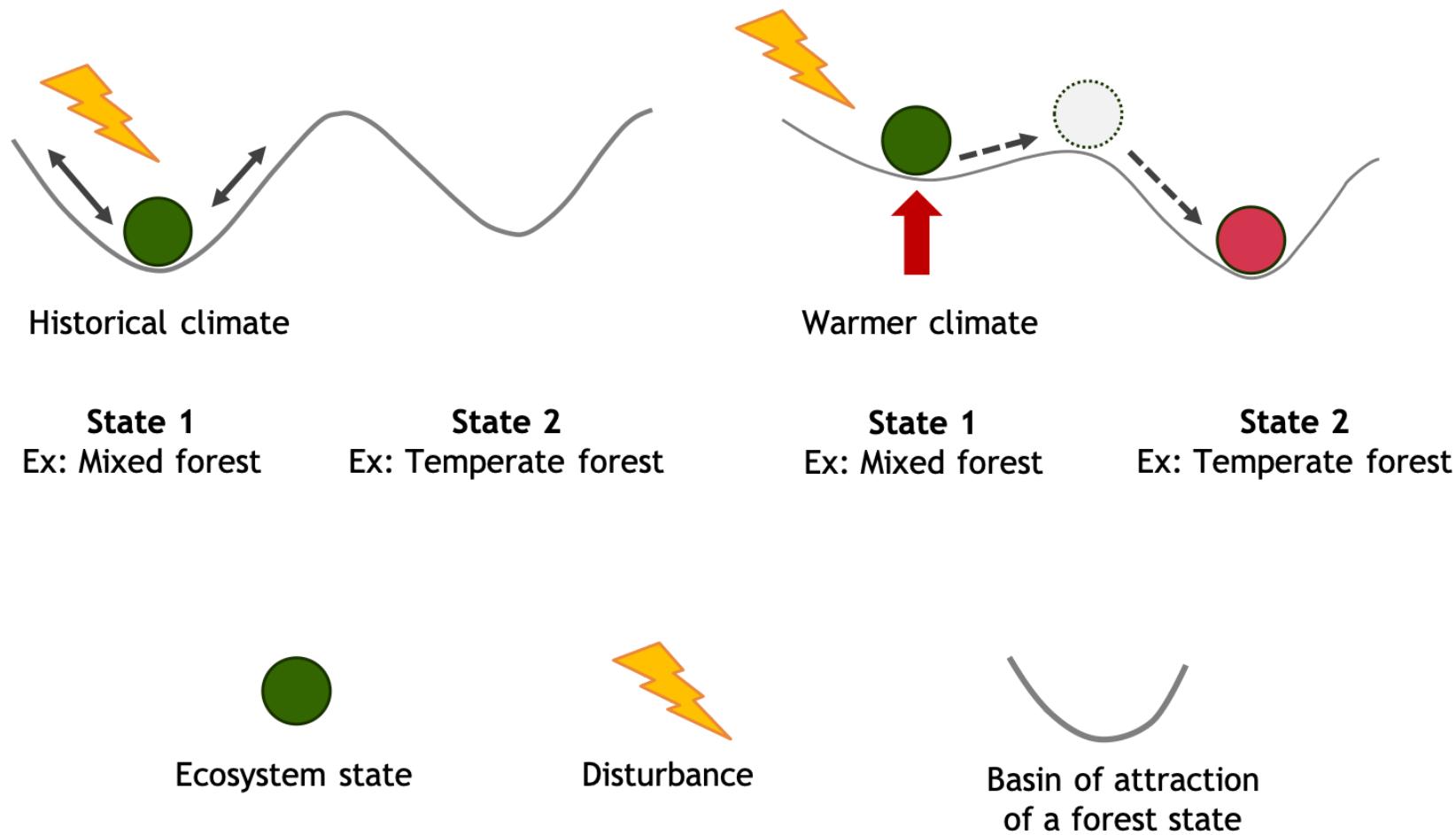
Prédiction



Réalité



Alternative stable states



Johnstone et al. 2016

Understand the constraints and drivers underlying the transition dynamics of Quebec's forests.

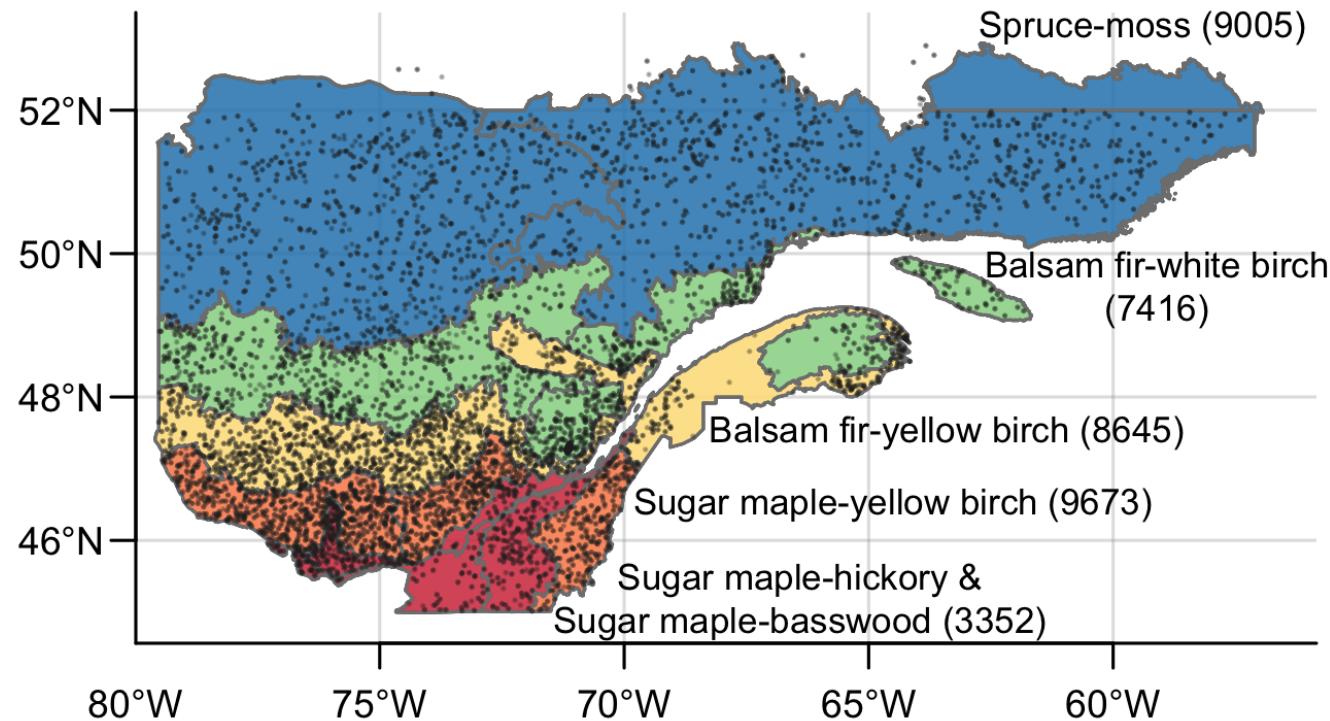
- ① What are the trends in recent forest transition dynamics?
- ② How do disturbances influence the transition probabilities among forest states?
- ③ What is the impact of different disturbance intensities on the potential equilibrium and transient dynamics?



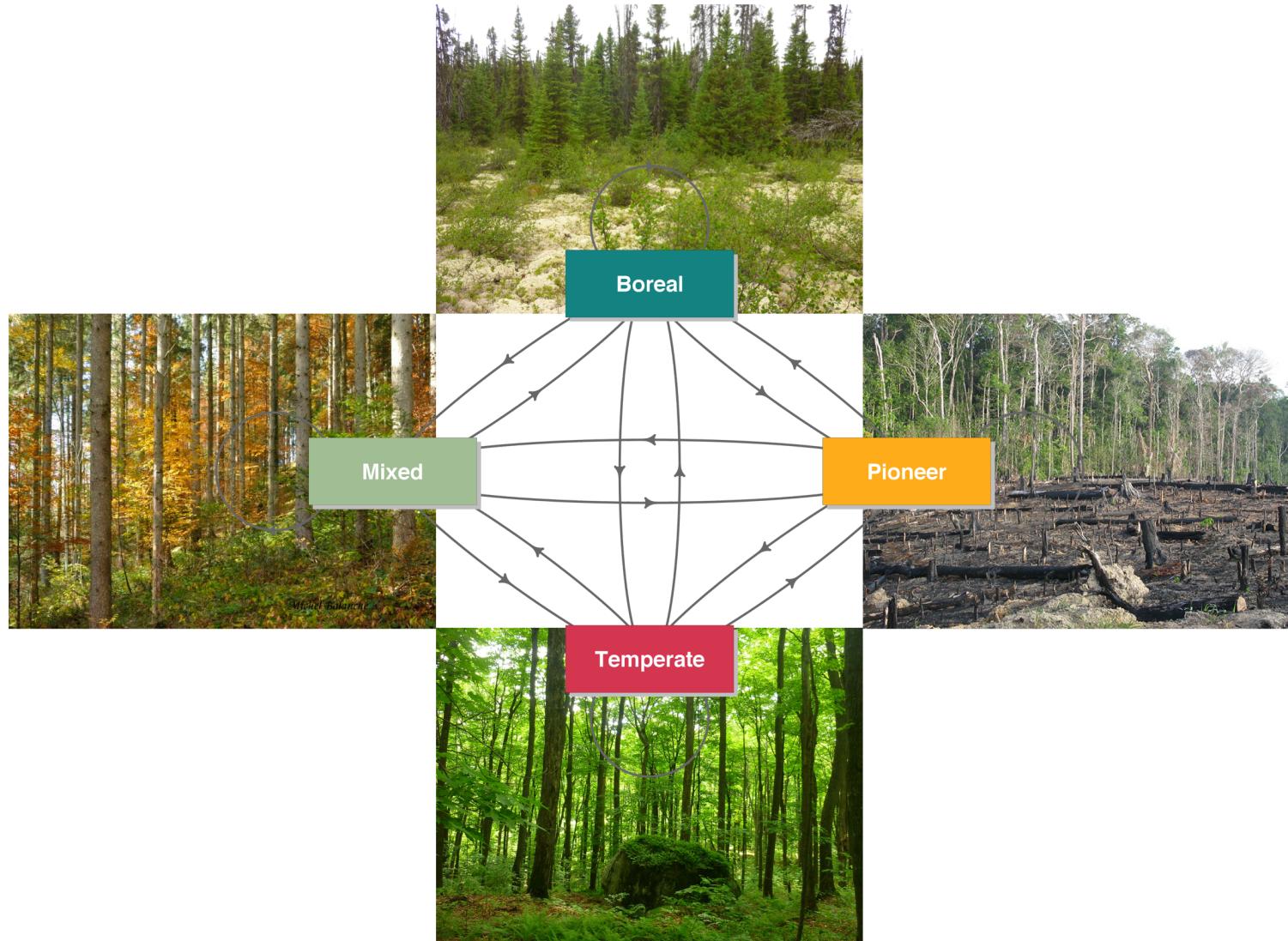
Forest inventory data

Québec forest inventories

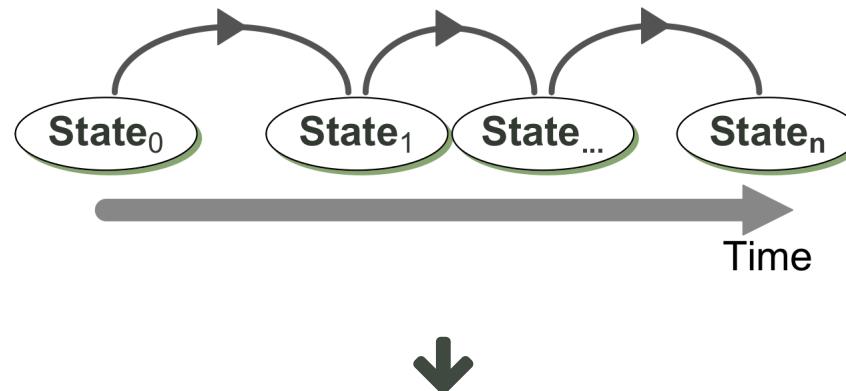
- 12000+ permanent plots sampled during 5 large inventories between 1970 and 2018 (by the MFFP)
- Selection of 11058 plots surveyed at least twice each



Forest inventory data



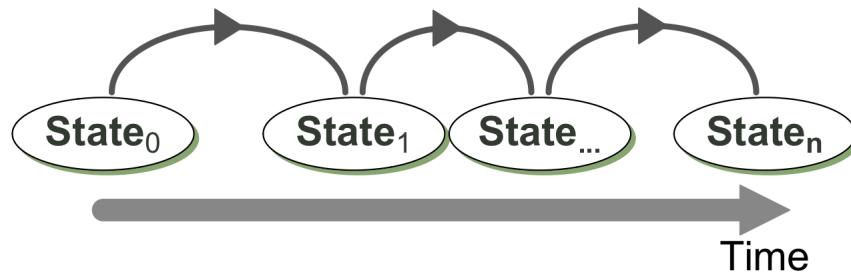
Multi-state Markov model in continuous-time



We model the intensity matrix Q containing instantaneous transition risks among states (row to columns) in relation to environmental variables.

$$Q = \begin{pmatrix} -\sum_{s \neq B} q_{Bs} & q_{BM} & q_{BP} & 0 \\ q_{MB} & -\sum_{s \neq M} q_{Ms} & q_{MP} & q_{MT} \\ q_{PB} & q_{PM} & -\sum_{s \neq P} q_{Ps} & q_{PT} \\ 0 & q_{TM} & q_{TP} & -\sum_{s \neq T} q_{Ts} \end{pmatrix}$$

Multi-state Markov model in continuous-time



Climate

🌡️ Growing season temperature at t_{i-1}

🌧️ Climate Moisture Index (CMI) at t_{i-1}

Soil

⼟ Soil pH

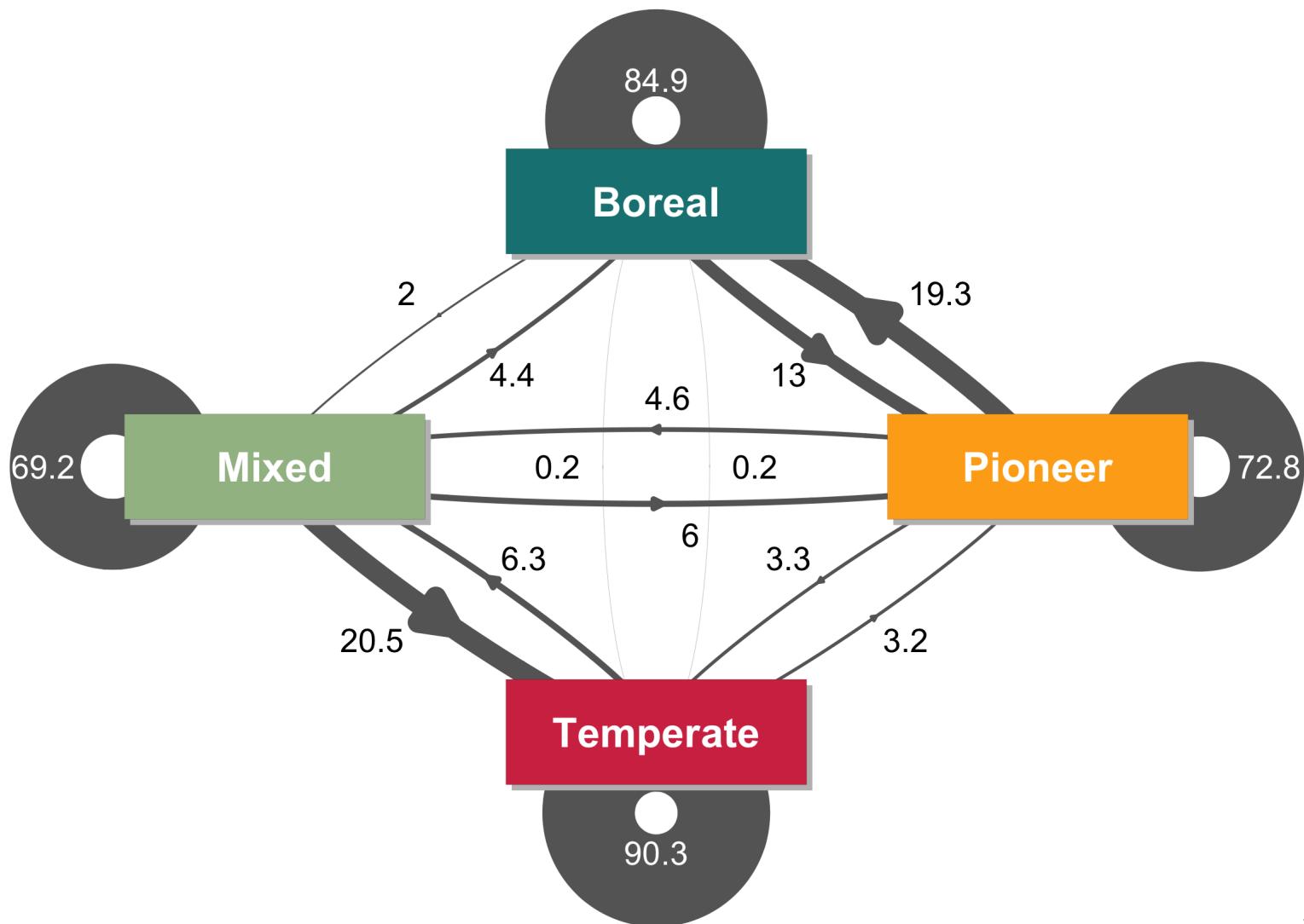
💧 Soil drainage

Disturbances

🔥 Natural disturbances between t_{i-1} and t_i

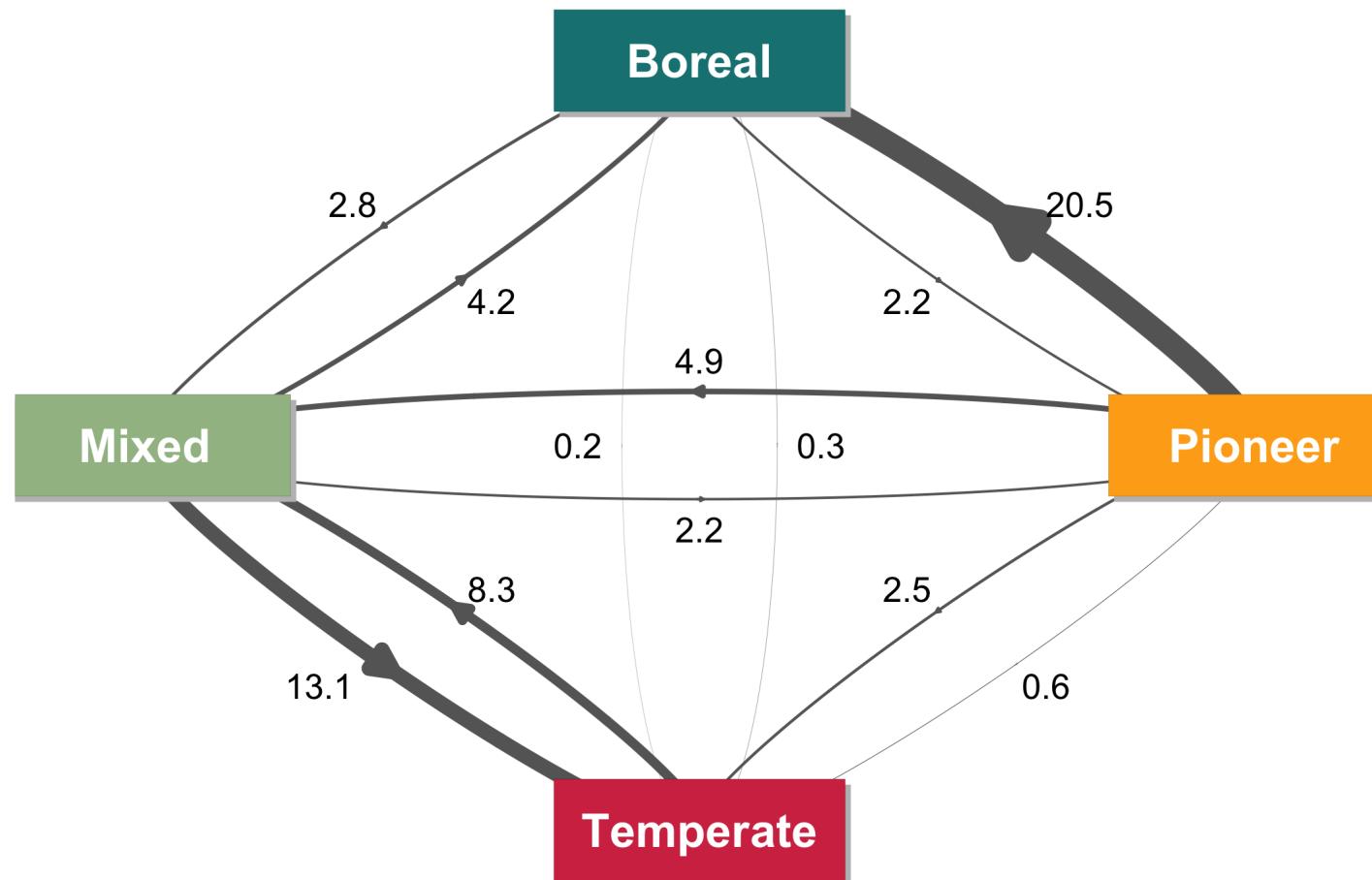
🌲 Logging between t_{i-1} and t_i

Observed transitions



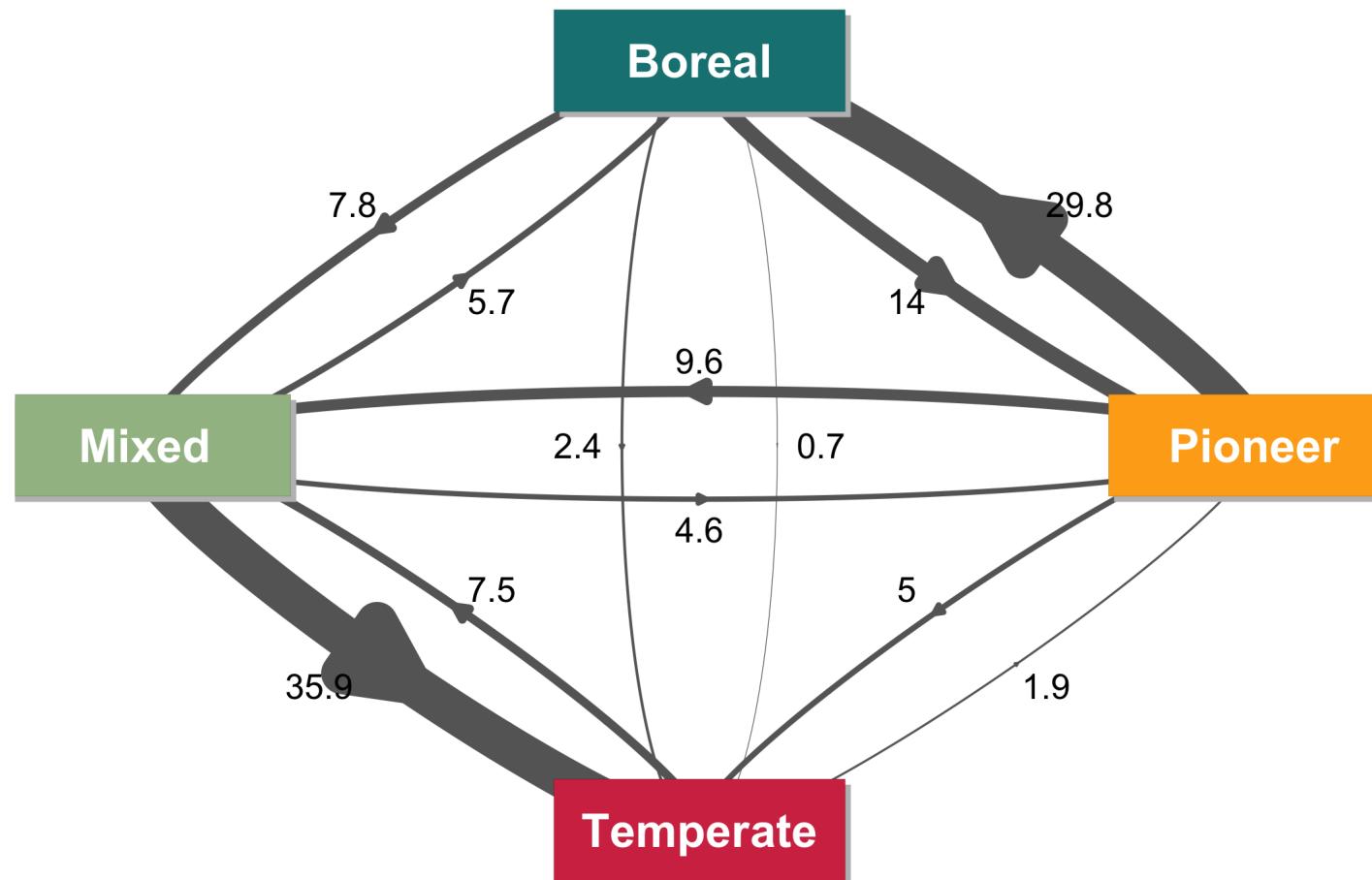
Transition probabilities

No or minor logging



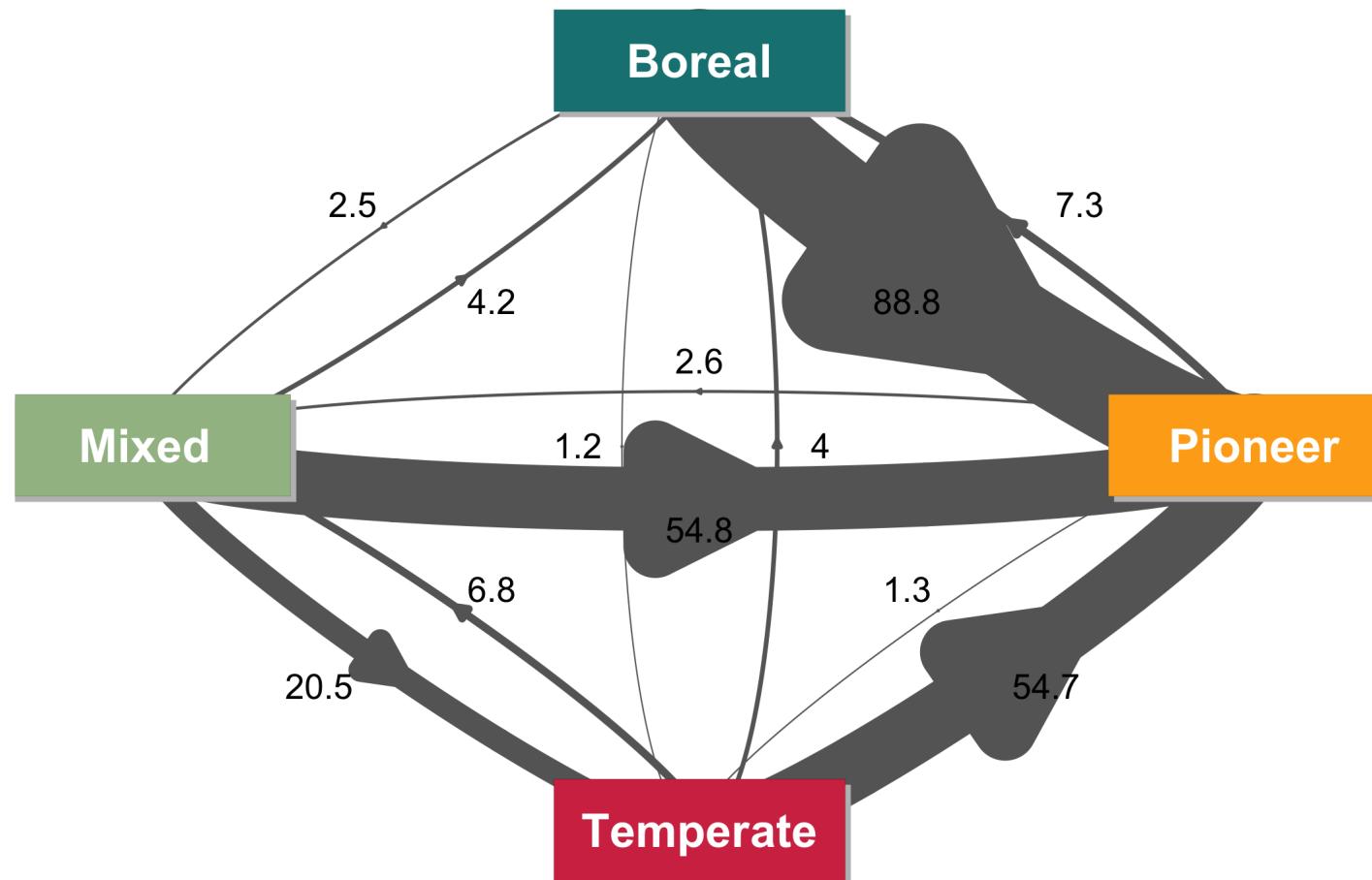
Transition probabilities

Moderate logging

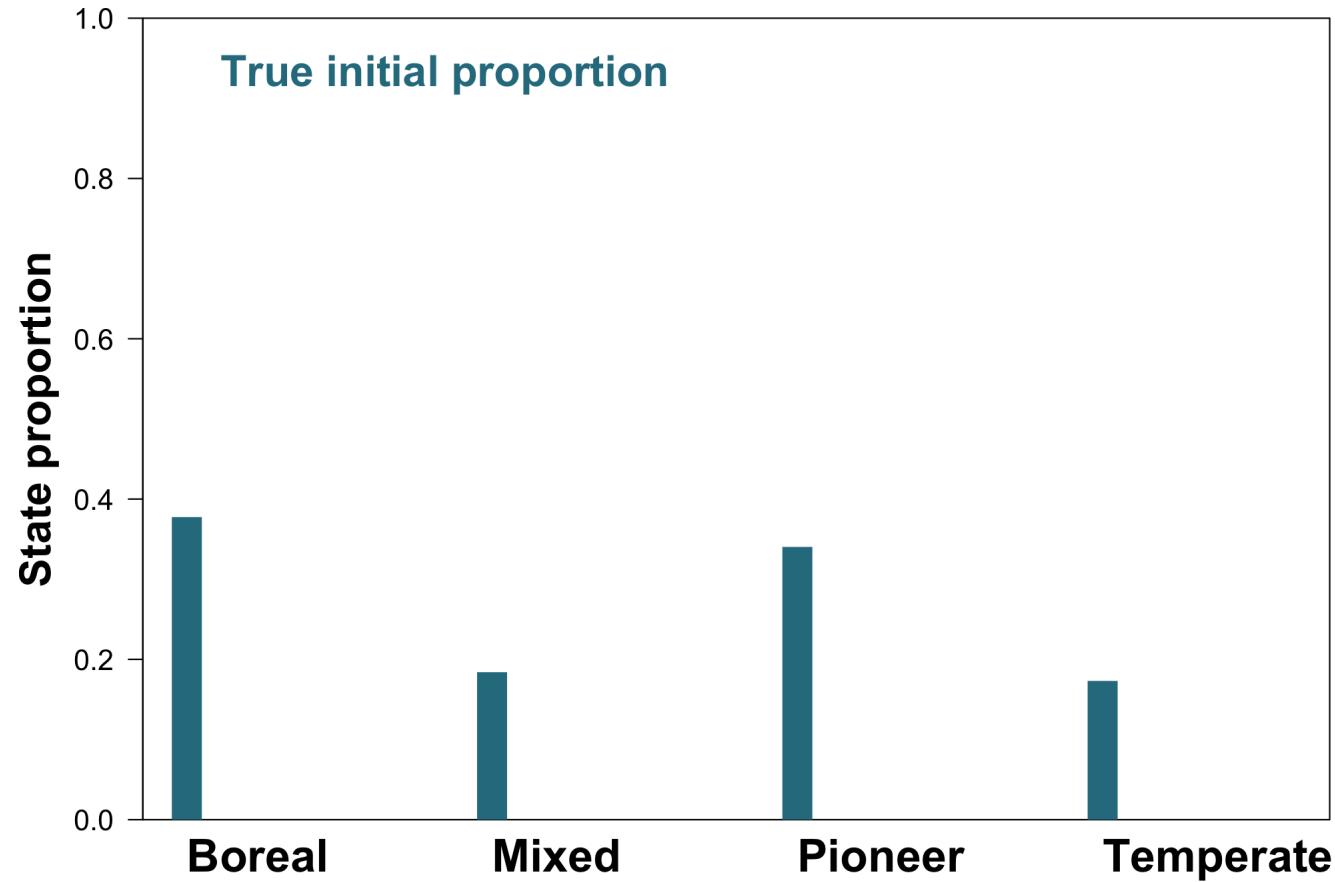


Transition probabilities

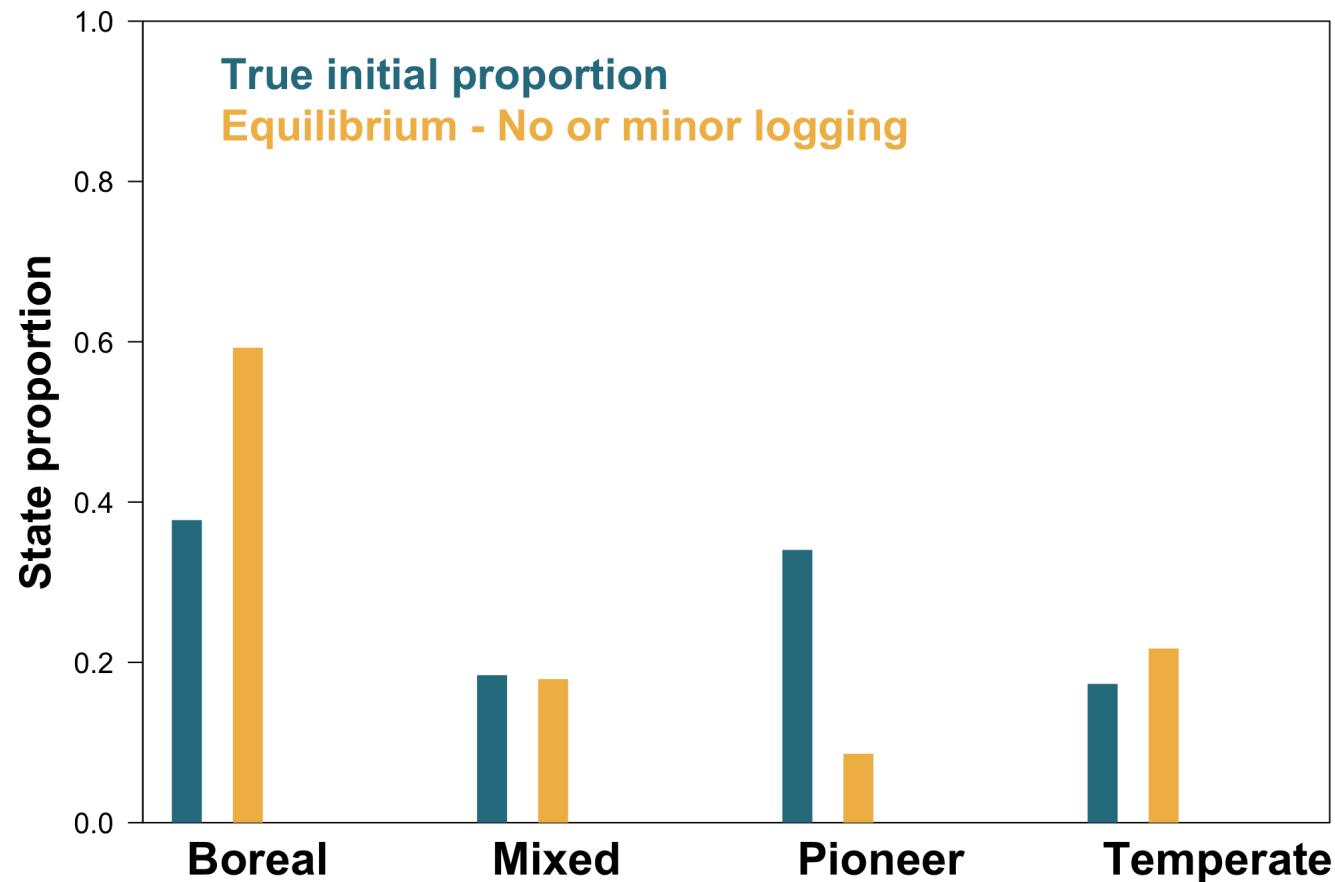
Major logging



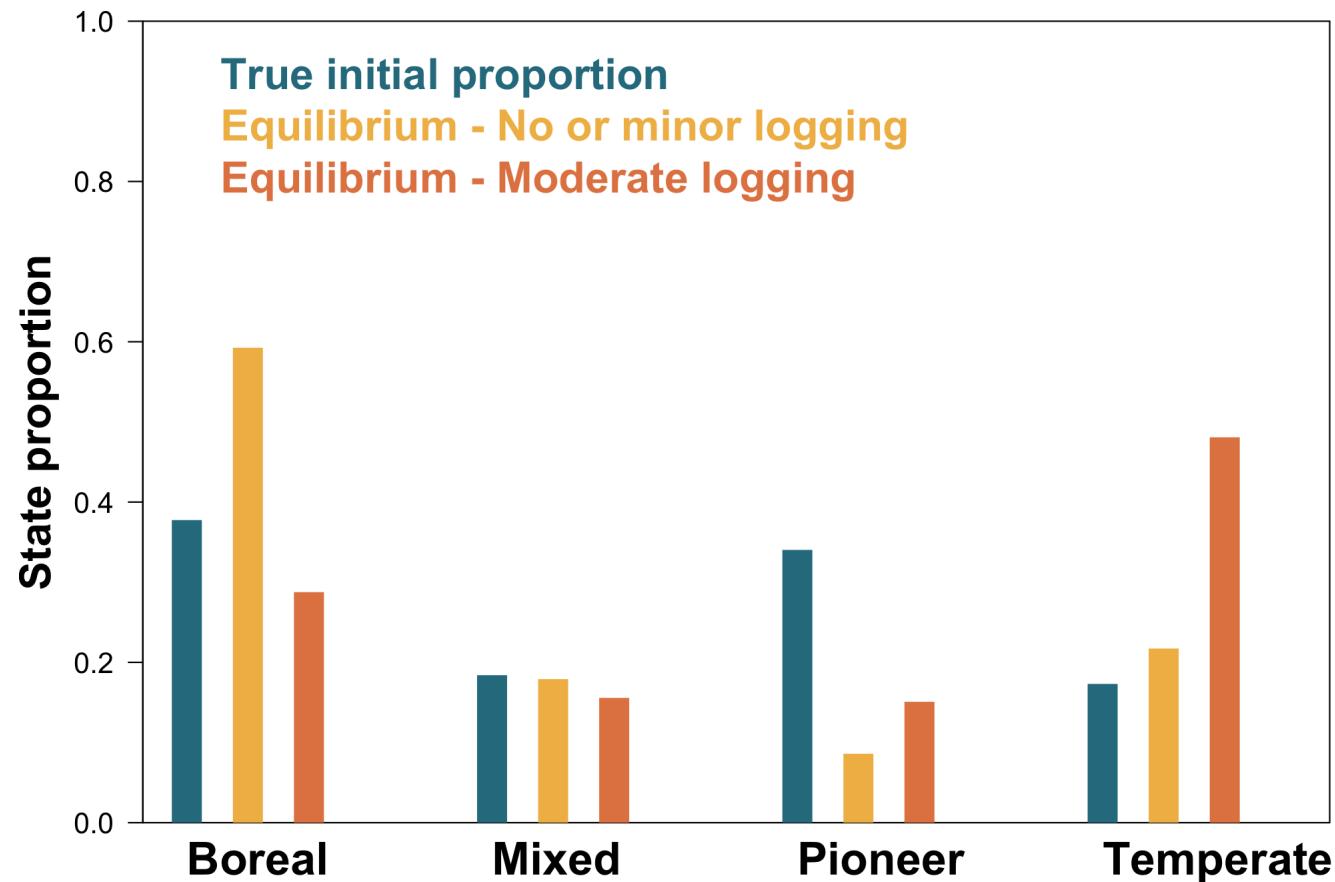
Potential equilibrium proportion



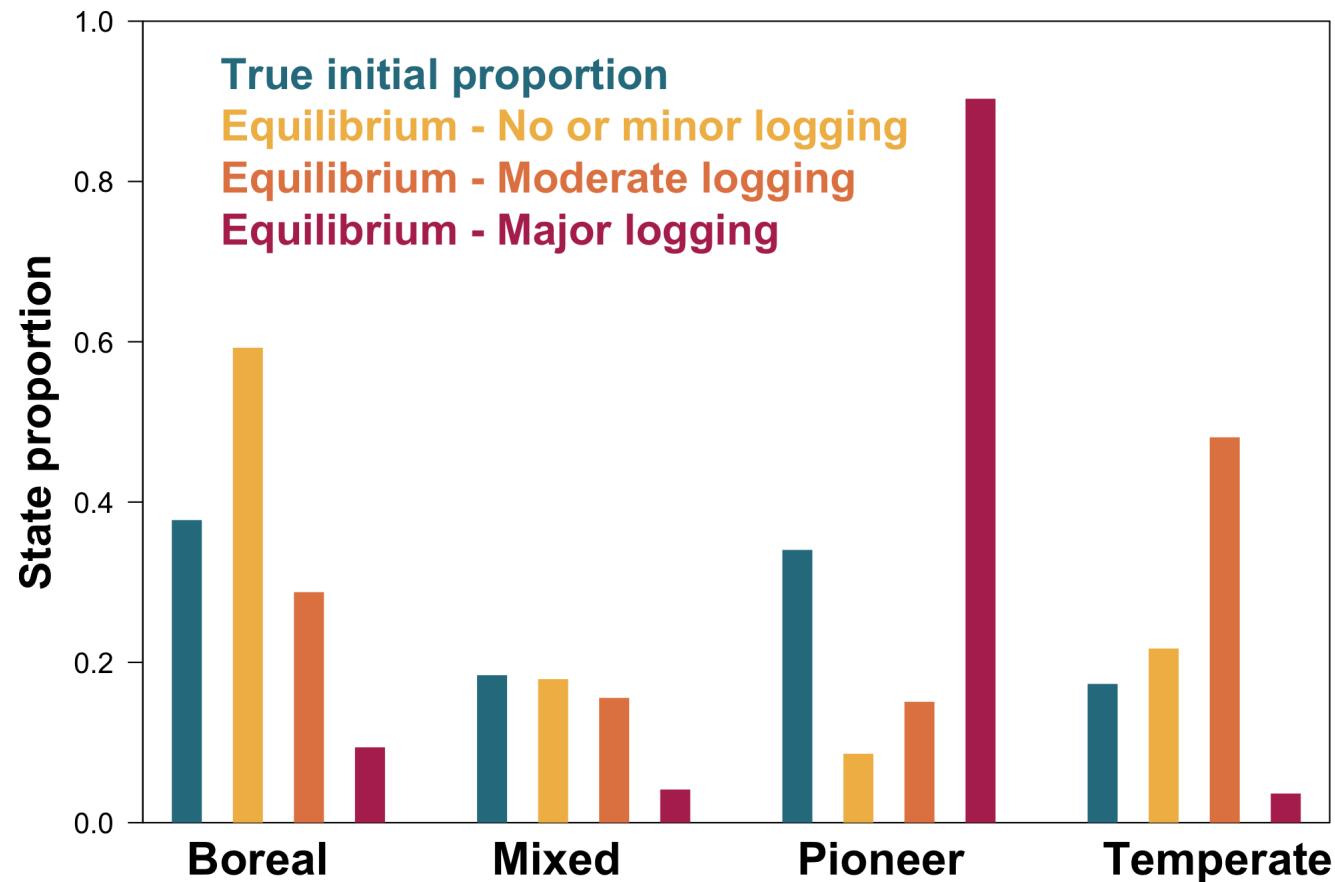
Potential equilibrium proportion



Potential equilibrium proportion

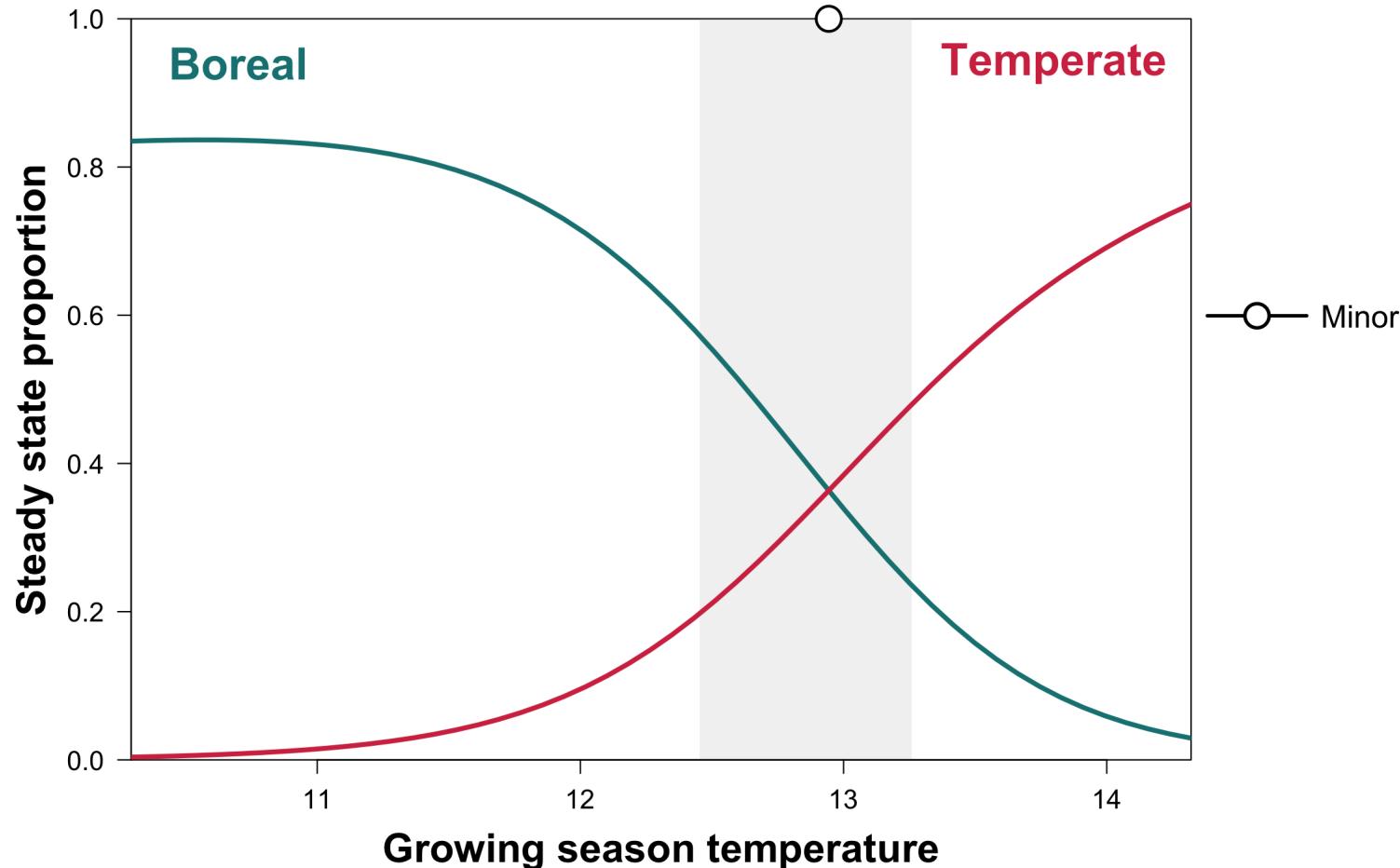


Potential equilibrium proportion



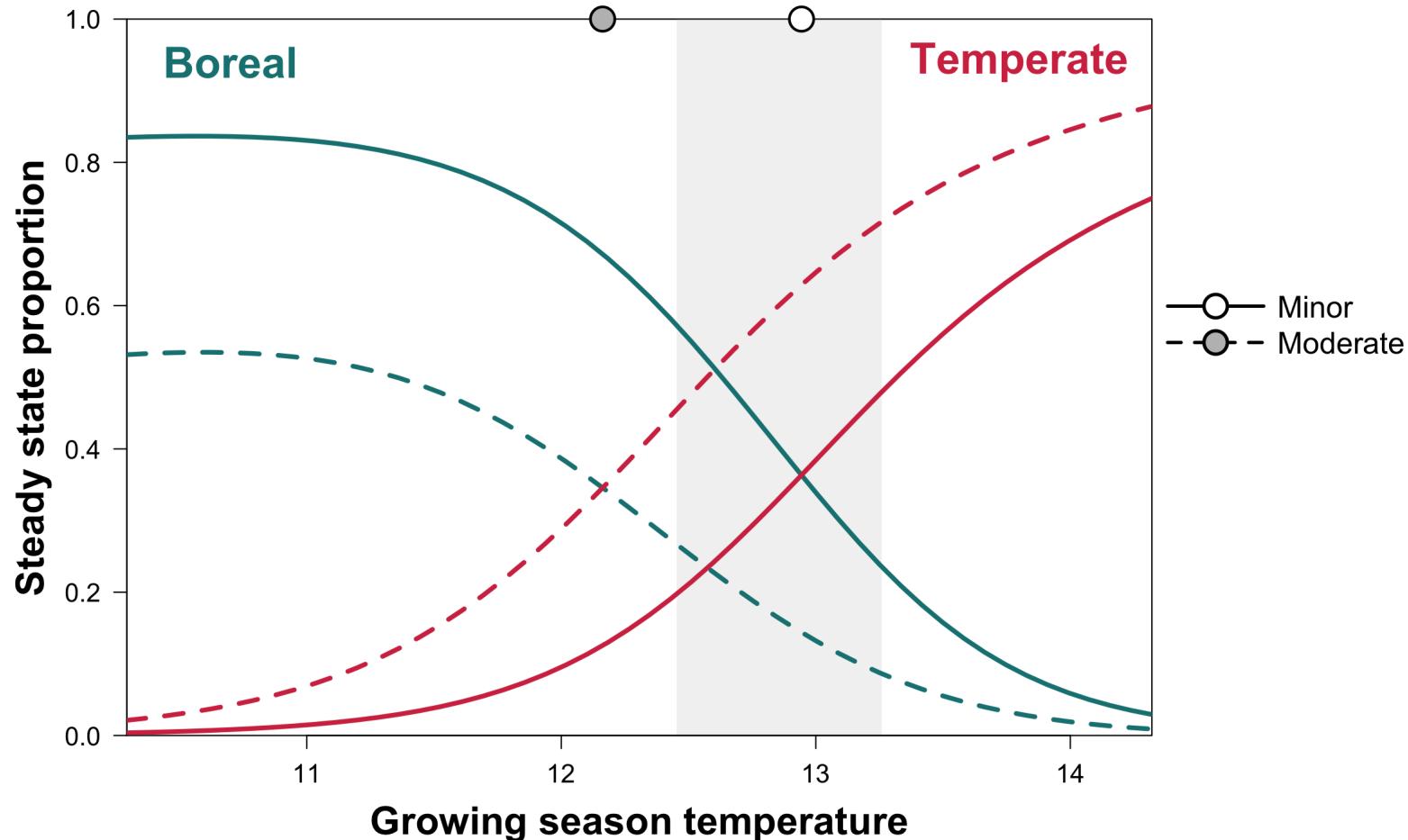
Ecotone shift at equilibrium

No or minor logging



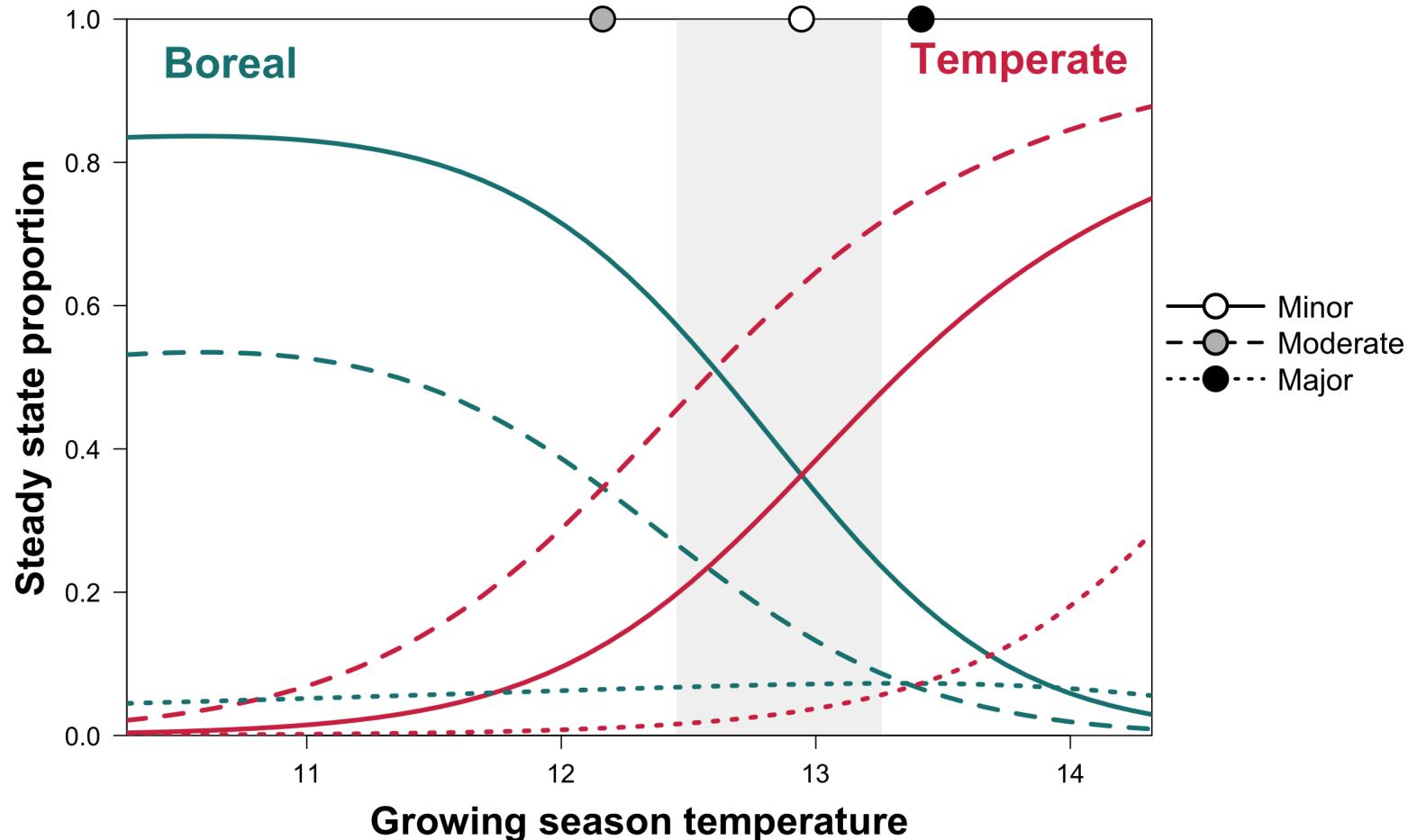
Ecotone shift at equilibrium

Moderate logging



Ecotone shift at equilibrium

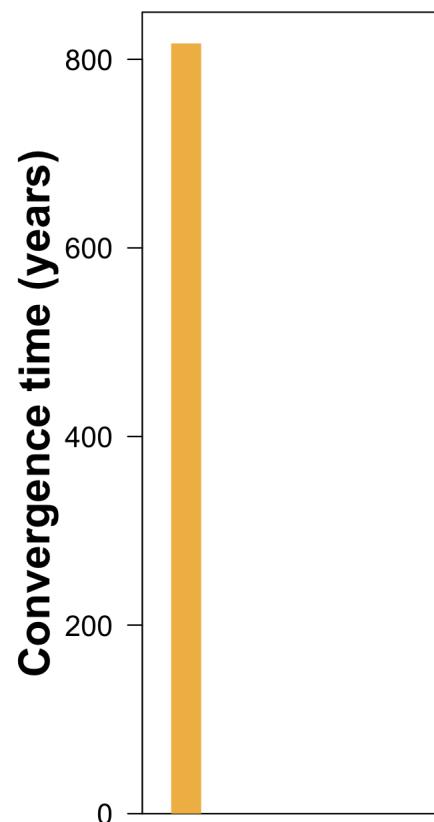
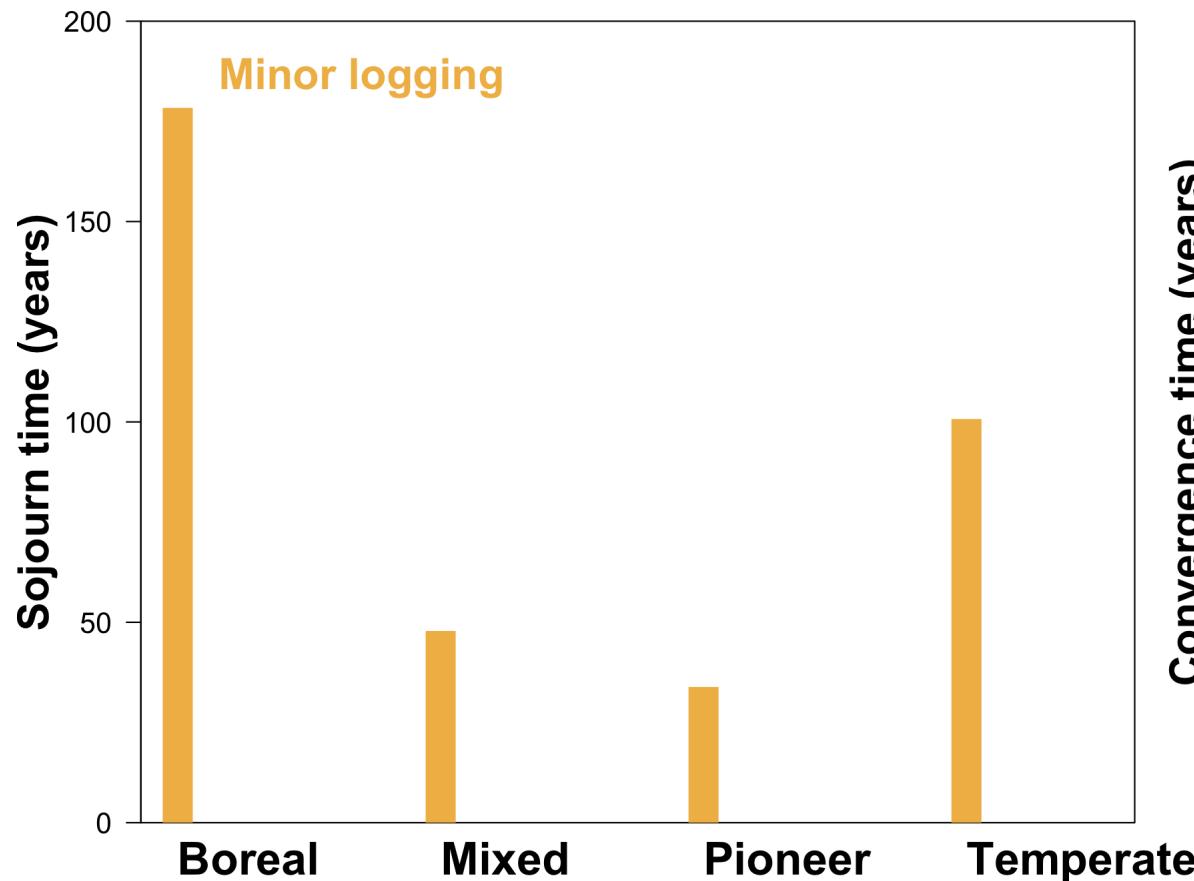
Major logging



Transient dynamics

Sojourn time → turnover; time spent in a state before making a transition

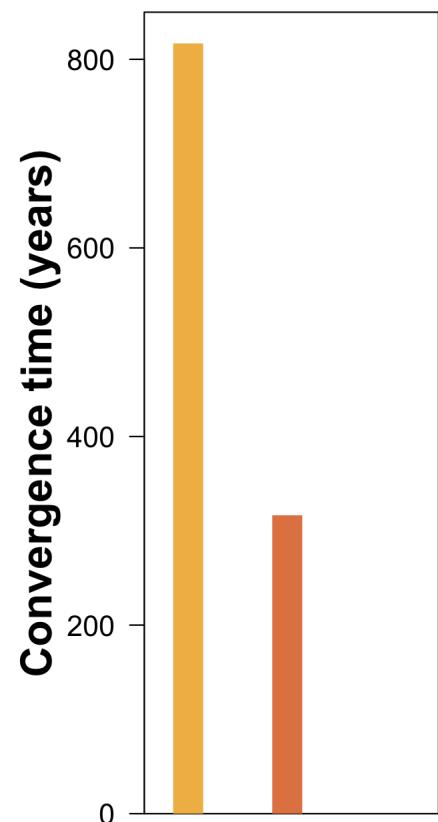
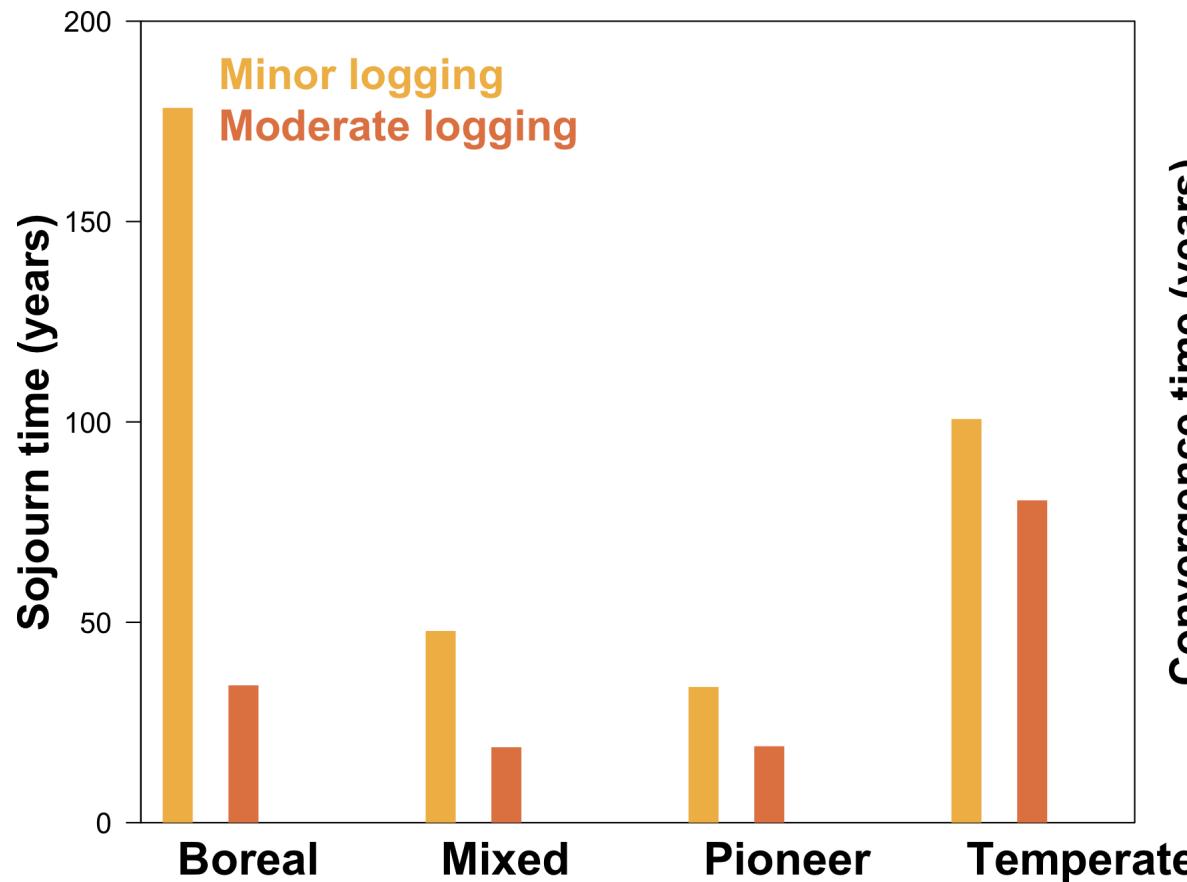
Convergence time → time to reach 90% of the equilibrium



Transient dynamics

Sojourn time → turnover; time spent in a state before making a transition

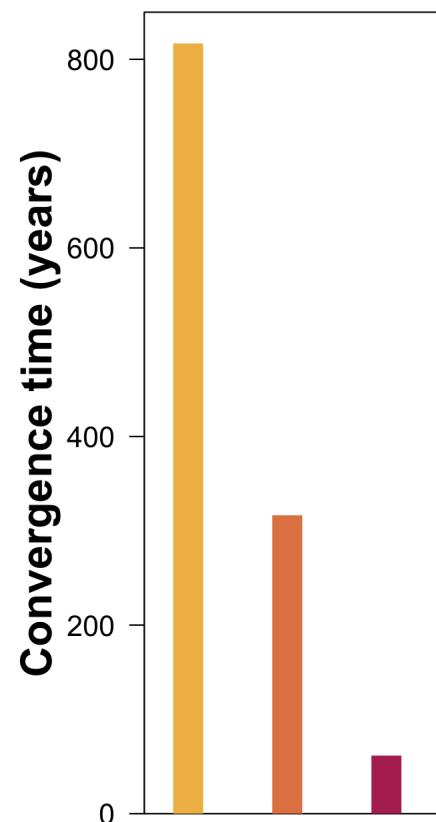
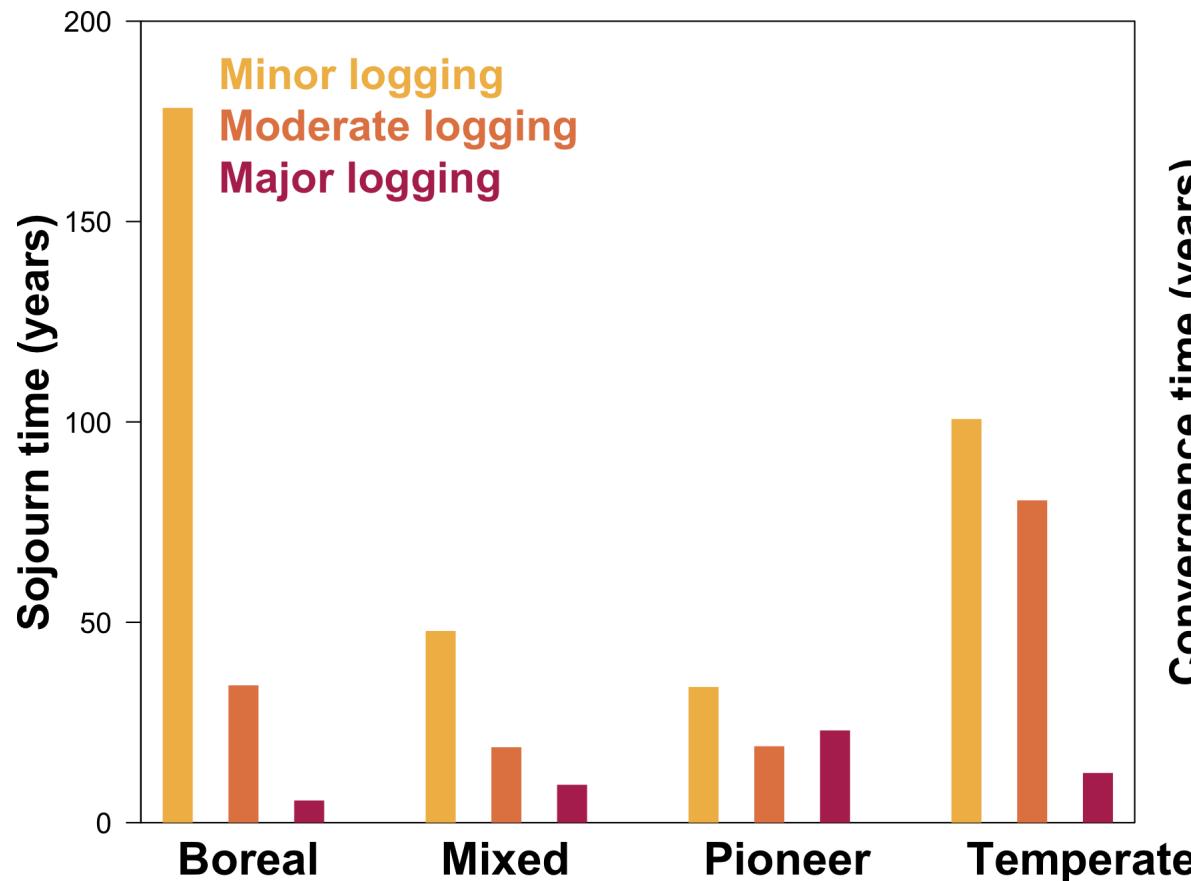
Convergence time → time to reach 90% of the equilibrium



Transient dynamics

Sojourn time → turnover; time spent in a state before making a transition

Convergence time → time to reach 90% of the equilibrium



Conclusions

① What are the trends in recent forest transition dynamics?

Strong regeneration of boreal forests in response to disturbances in the 70s.

Conversion from mixed to temperate stands in response to climate change.

② How do disturbances influence the transition probabilities among forest states?

Yes. Moderate disturbances, not major, favour Mixed-Temperate transitions.

③ What is the impact of different disturbance intensities on the potential equilibrium and transient dynamics?

Moderate disturbances, not major, tend to increase the proportion of Temperate at equilibrium, moving the ecotone northward.

Moderate disturbances, not major, accelerate transient dynamics.

Ecological and management implications

So...

Should we cut down trees to accelerate forest transitions?



Multi-state model results

