Special session: Fire as an evolutionary pressure shaping plant traits

Fire shapes plant traits

Introduction &
Evidence from the Mediterranean Basin

Juli G. Pausas
CIDE-CSIC, Valencia, Spain
www.uv.es/jgpausas

MEDECOS XII, Los Angeles, 9/2011

Fire shapes plant traits

CONTENTS

- How our perception of fire has changes
- Misconceptions: Adaptation vs Exaptation
- Contributions from macro- and micro evolutionary approaches
- Mediterranean Basin examples

Fires as disasters

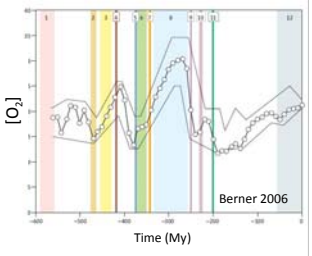
- They burn ecosystems!
- Static, short view
- Outdated view

Fire as an ecosystem process

- Ecosystems regenerate after fire
- Fire changes community structure and ecosystem functioning
- Now widely accepted
- Example: Grass – fire cycle (feedbacks)

Fires as an old phenomena

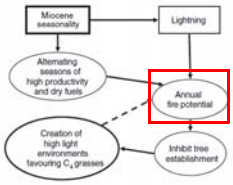
- Charcoal: from Silurian (>415 My) …
- Periods of higher [O_2]: high flammability
- Started to be recognised



Belcher et al. 2010 PNAS
Bond & Scott 2011 New Phytol
Pausas & Keeley 2009 BioSci

Fire as an old ecosystem process

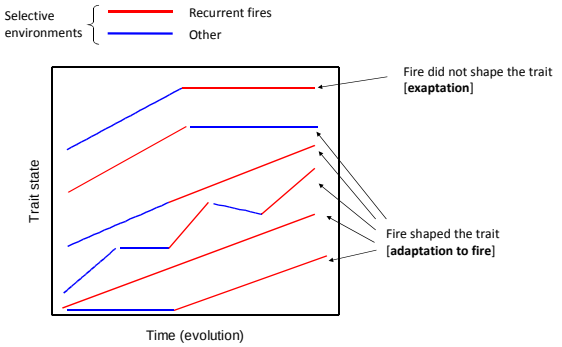
- Expansion of C_4 grasses, Miocene (Keeley & Rundel 2005)
- Expansion of Angiosperms, Cretaceous (Bond & Scott 2011)



Fire as an evolutionary process

- Growing evidence that fire acted as a selective force in the evolution of plants (adaptations to fire)
- Hard to believe for many …
- "Fire traits are not adaptations but exaptations"

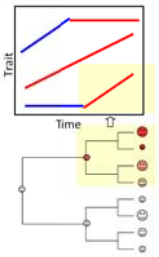
Adaptation vs Exaptation



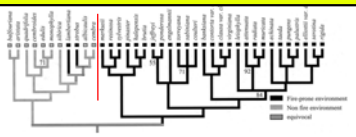
How do we differentiate among alternative scenarios?

Is fire shaping traits?

- Macro-evolutionary approaches:
  - Molecular data: time-calibrated phylogenies
  - Correlated evolution
  - Ancestral reconstructions



Macro-evolution: early studies

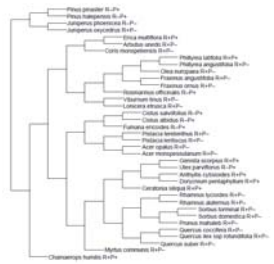


Pinus

Basal split between fire-prone and non fire-prone pines

No dating

Schwilk & Ackerly 2001 Oikos



R: resprouting
P: seeding

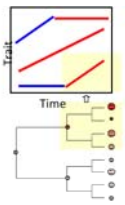
Temporal order in the adquisition of fire traits R+, P+

No dating

Pausas & Verdú 2005 Oikos

Macro-evolution: recent evidence (2011)

- The blooming of molecular data: dated phylogenies

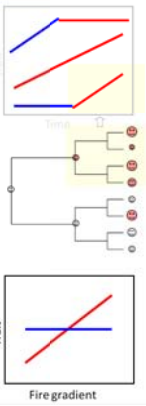


Taxa	Trait	Age (Mya)	Ref.
Disa Orchidaceae ZA	Fire-dependent flowering	19.5	Bytebier et al. 2011 *Proc R.S.L.*
Eucalyptus Myrtaceae AU	Epicormic resprouting	60-62	Crisp et al. 2011 *Nature Coms.*
Banksia Proteaceae AU	Serotiny Dead leave retention	62 26-16	He et al. 2011 *New Phytol.*

> 60 My of fire as an evolutionary process shaping plants

Is fire shaping traits?

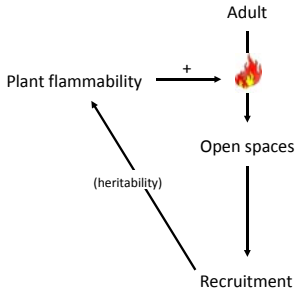
- Macro-evolutionary approaches:
  - Molecular data: time-calibrated phylogenies
  - Correlated evolution
  - Ancestral reconstructions



- Micro-evolutionary approaches
  - Trait divergences between populations under different fire regimes
  - Differential fitness among phenotypes
  - 2 examples from the Mediterranean Basin

1. Trait divergence: flammability

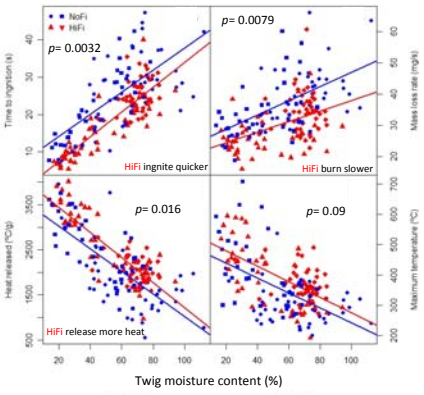
Seeder species



H: recurrent fires enhance flammability

(Bond & Midgley 2005)

Flammability: *Ulex parviflorus*

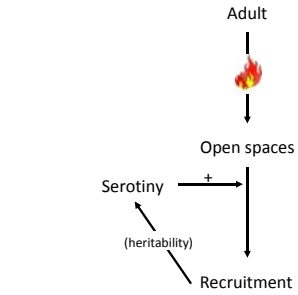


Obligate seeder
E Spain

Selective environments:
HiFi: Recurrently burned
NoFi: Oldfield colonization

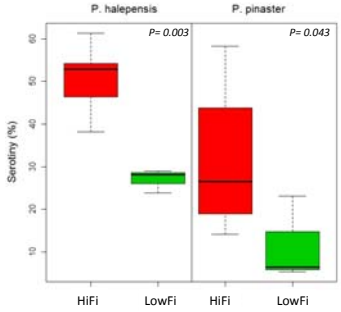
Flammability: HiFi > NoFi
Trait divergence

2. Trait divergence: serotiny



H: recurrent fires enhance serotiny

Fire enhances serotiny



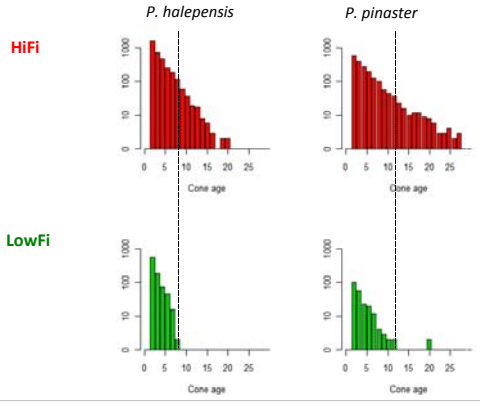
HiFi: Populations recurrently burned in crown-fires

LowFi: Populations rarely burned in crown-fires

Serotiny = # closed [>1yr] / total cones

GLMM
Random= Site
Fixed= Fire

Fire enhances serotiny



Conclusions

- Phylogenetic studies unambiguously show that fire **has been** a selective force shaping traits for very long, at least since Palaeocene (60 My), but probably longer (studies are coming)
- There is field evidence suggesting that **currently**, different fire regimes selects different traits (natural selection in action)
  - More studies, including genetic studies (heritability, etc.) are still needed

The co-evolution of serotinous cones and thick bark

Thanks!

Collaborators:
B. Moreira
A. Hernández
G. Alessio
G. Corcobado

Projects:
VIRRA
VAMPIRO

Cones of *Pinus halepensis*; Bark of *Quercus suber;* From: Tunisian market