# How influential is herbivory, both native and exotic, in shaping Australian vegetation patterns?

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# Herbivory : a recent driver of ecological change

*"Fire is considered to be the major landscape scale disturbance regime that structured Australian Ecosystems before European Settlement"*

**Bradstock** et al. 2002 "Flammable Australia: the fire regimes and biodiversity of a continent" CUP

*"Ecologists believe the infertile soils and the very low or seasonal rainfall of central and northern Australia may have prevented the sustainable herds of large mammals of other continents. Instead termites became the dominant year round herbivores and nutrient-cyclers"*

**Michael Soulé** ABC Radio National

*"Since European settlement the livestock industries and associated land management activities have greatly degraded many Australian ecosystems and its legacy will be long-lasting to permanent in many areas."*

**Lunt** et al. 2007. Turner review #13. Aust J. Bot.

# Outline

- **Vertebrate herbivory**
  - **impacts on Australian vegetation**
  - and Climate change
- Invertebrate herbivory
  - Generalists
  - Specialists
- Herbivory drivers of plant invasions
- Herbivory-driven CC research needs

# Vertebrate herbivory

## Herbivore density and vegetation impact drivers

1. Water-point provision (now averages 1 every 10 km)
2. Overstorey tree removal
3. Introduction of grazing-adapted alien plants
4. Dingo reductions

(James et al. 1999)

## Stepwise selective grazing behaviour

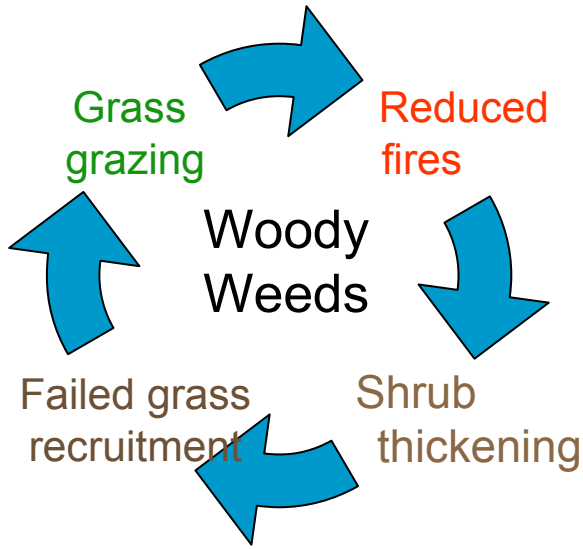
- Preferred species selectively grazed until its abundance drops below a critical threshold then…
- Next preferred species selected …. etc.
- Selectivity declines with grazing pressure
- High grazing pressure & soil degradation has lead to "catastrophic vegetation shifts" (*sensu* van de Koppel 1997)

# Impacts of vertebrate herbivory

Changes in:

- species dominance (Lodge & Whalley 1989)
- plant trait assemblages (McIntyre & Lavorel 2007)
- vegetation structure → unpalatable shrubs (Westoby et al.1989)
- palatability gradients near water points (Landsberg et al. 2003)
- exotic species invasions (Prober et al. 2002)

- "Vegetation thickening" – loss of herb layer communities
  - Woody weed encroachment in rangelands (Archer 1995)
  - NT Riparian savannah grasslands → impenetrable shrubs over exotic fire resistant shrubs (Sharp & Whittaker 2003)
  - Alpine zone cattle grazing 50 yr trends reduces palatable tall herbs and shrubs, but allows unpalatable exotic shrubs and trees (Wahren et al 1994)



# Impacts of vertebrate herbivory

- Shrubs → grassland
  - W NSW semi-arid palatable saltbush Acacia shrub → native grasslands (Moore 1953)
  - Tree/shrub regeneration in intensely grazed temperate agricultural landscapes → senescent paddock trees (Reid & Landsberg 2000)
  - Feral animals also responsible for shrub/tree recruitment failure
- Perennial → annual grasslands
  - Temperate grasslands and woodlands (Moore 1967)
  - Sub-alpine tussock grassland degradation (Halloy & Mark 2003)
- Abiotic degradation - soil & ecosystem processes – water, nutrient flows & fire regimes – affecting vegetation recruitment
  - Riparian degradation in many regions (Jansen & Robertson 2001, Price & Lovett 2002)
  - Sphagnum bog degradation in alpine wetlands (Wahren et al. 2001)
  - leakage in run-on resource-rich Mulga groves (Ludwig et al. 1997)
- Direct biodiversity loss – 34 spp. extinct, 51 spp. endangered, 55 spp. threatened (Leigh & Briggs 1992)
- Indirect biodiversity loss – 100's species threatened by exotic "increaser" pasture grasses and pasture weeds (Scott in prep)

# Biodiversity benefits from vertebrate grazing (Lunt *et al*. 2007)

**Practical application of "intermediate-disturbance hypothesis" - moderate grazing can ▲ diversity by suppressing palatable dominants**

**Ecosystem fertility driven – benefits only likely in invaded communities or grass dominated communities on fertile soils – fertility giving higher resilience?**

- To reduce biomass of existing or encroaching dominant undesirable grazing-sensitive palatable plants
- To provide disturbance niches for rare species that need them (i.e. non-fire adapted species)
- As a tool to diversify vegetation structure across the landscape
- To restore highly degraded ecosystems through specific intensive management strategies
- As a more viable alternative to fire

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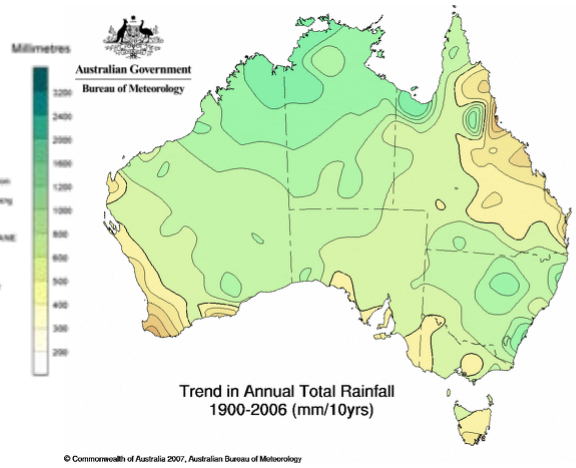
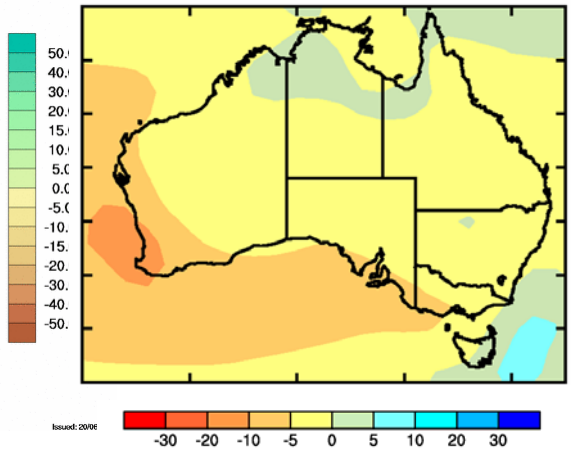
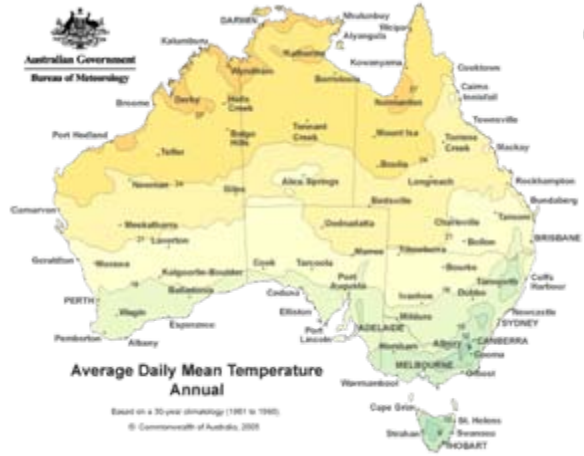
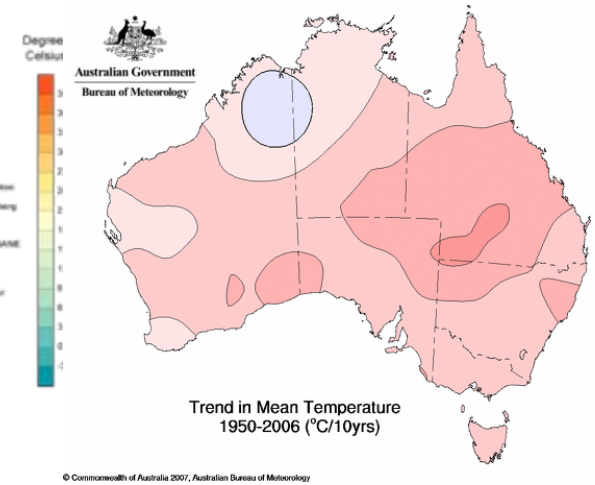
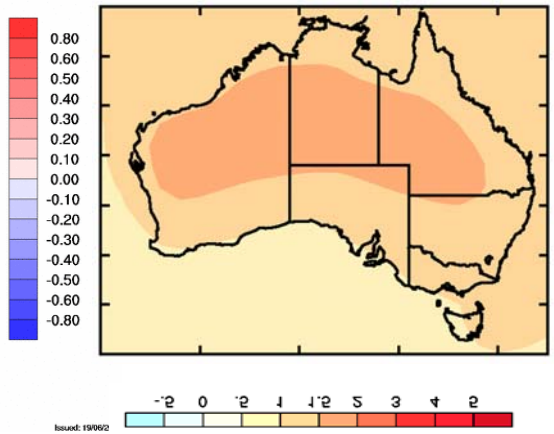
# Rainfall & Temperature

# Some observations

Recent *Eucalyptus pauciflora* expansion into Alpine grasslands grazing x climate interaction? (Wearne & Morgan 2002)

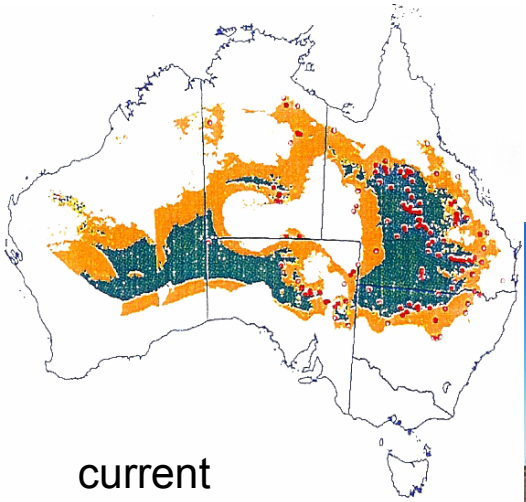
Rabbits increasing in altitudinal range (rabbit control at Perisher blue) – posing significant threats on alpine diverse herb-rich communities (Green & Pickering 2002).

# Some arid-zone predictions

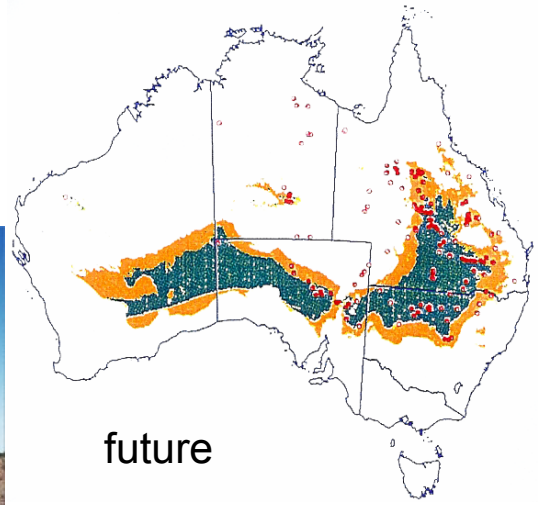
Predicted erratic wet-drought and temp extremes leading to shifting and intensification of existing vegetation patterns (Hughes 2003)

Example: Mitchell grasslands

potentially 70% ▼ - suitable climate x soil type interactions



current



future

(Chapman & Milne 1998)

# Current understanding

**Climate Change in Australia: Trends, projections & impacts**

Hughes 2003 Aust. Ecol.

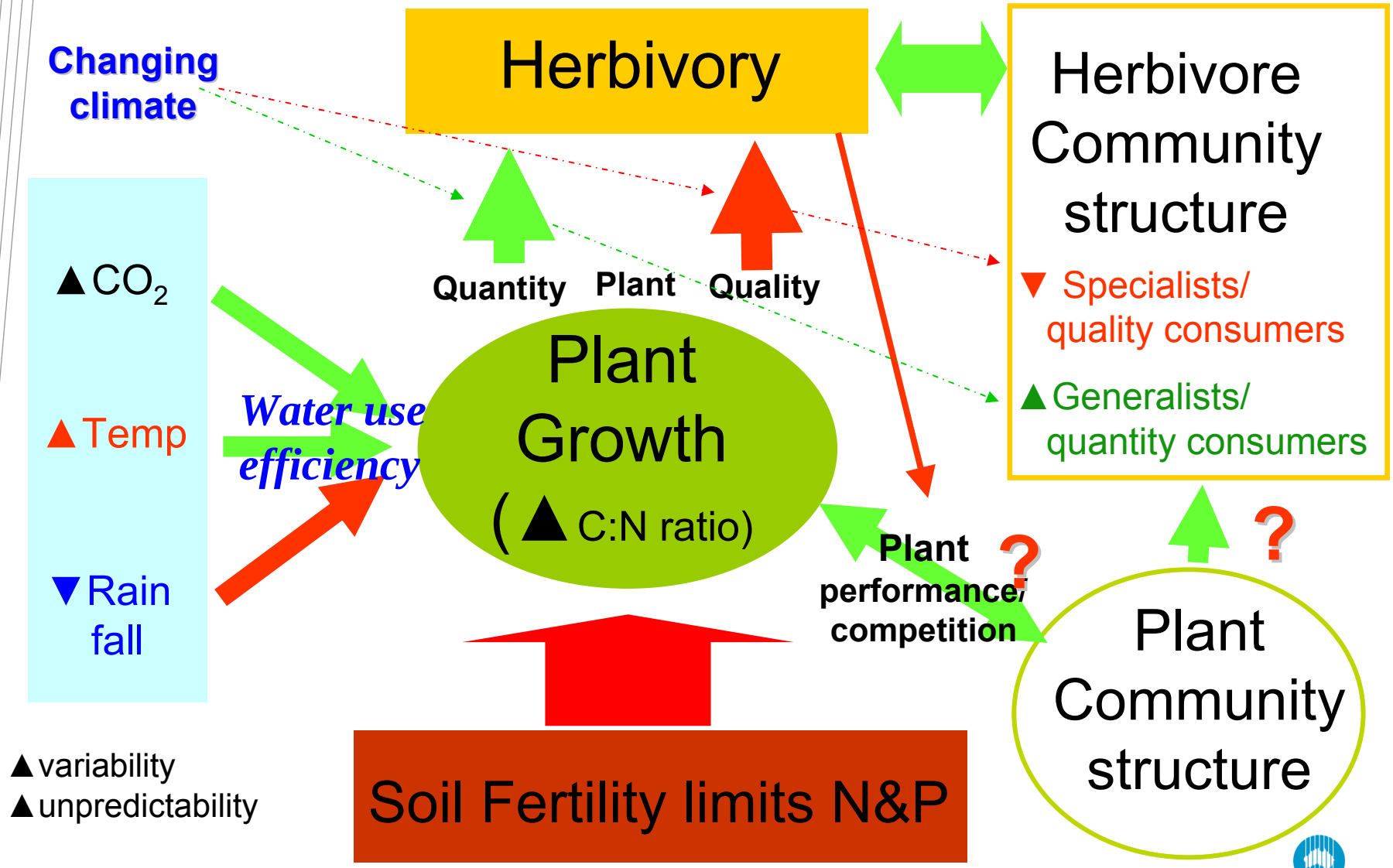
"***The few studies that have investigated the response of Australian plants to elevated $CO_2$ have focussed on single woody species…no published studies test the response of mixed stands or the interactions that occur in natural communities***"

**Biodiversity conservation research in a changing climate**

Hilbert et al. 2007 DEW Report

"***How will interactions between species be affected by climate change and how important these indirect impacts are compared to direct impacts … at present, we can only speculate***"

# Indirect effects of CC on herbivory: through climate-vegetation-habitat interactions

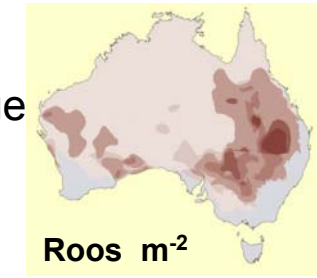


# Native & feral vertebrate herbivores

## - ½ total grazing pressure in some areas

### Culprits

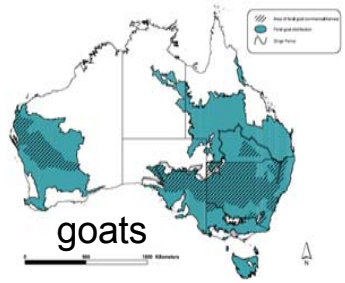
- *Kangaroo* (4 spp.) abundance generally rainfall dependent
  - selective grazer preferring riparian or post-fire fresh green foliage
  - water-points sustain artificially high densities in drought.–
  - overgrazing of native shrubs & grasses in some National Parks




- *Rabbits* – dominant feral

selective grazing – nutritious/palatable herbs, grasses,
Reduce/prevent shrub & ringbark small trees.
Interesting Fire x RCD x Climate interactions?

- *Goats* (2.6 M) the least selective browser/grazer
  - greatest impact on shrub vegetation & widespread in droughts




### Responses to CC

- ▲°C alone will have little impact due to physiological tolerances
- Distributions likely to show only minor changes

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# Direct effects of Insect Herbivores on plants

- **Growth**, mediating plant competition
- **Reproduction** (pollination; granivory)
- **Plant physiology** : e.g. photosynthesis & evapotranspiration
- **Sexual expression** (Thomson et al. 2004)
- **Population suppression**
- **Species distribution & habitat specialisations**
  (Fine et al. Science 2004)

*……Differences between generalists and specialists*

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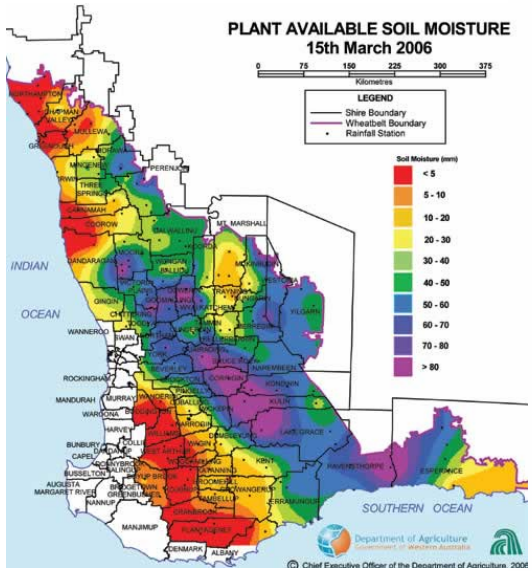
# Termites

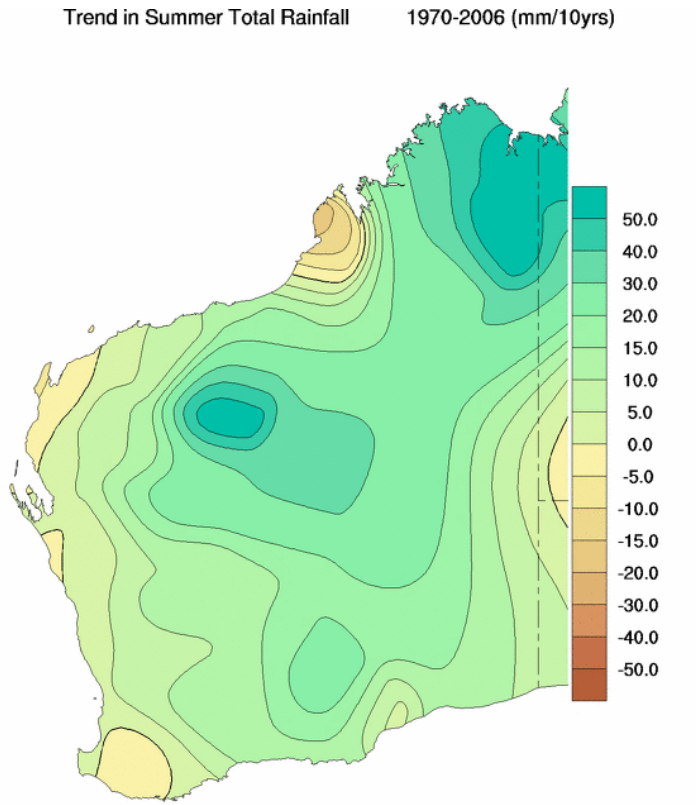
- Dominant herbivore in Australia's arid (high abundance) & tropical (high diversity) ecosystems – 40-120 kg $ha^{-1}$
- Low nutrient and drought adapted – active in dry season
- Know little about role of termite herbivory on ecosystem structure
- Warmer temps – termite spp. will move south esp. grass & litter feeders [>25°S].
- Future rainfall models suggest more woodlands in NW and grasslands (esp. Spinifex) in E
  - supports move S of grass feeding termites
- Wood feeding termites already most widespread – movements of more pest spp. to Tasmania?

# Australian plague locust

- Outbreaks – high summer rainfall events & available fallow land
- 1% of native pasture biomass can be consumed
- Trends show summer rainfall increases in key areas in WA
- Land abandonment increases under CC?
- Earlier egg-hatch occurring in S
- 2006 populations persisted for first time in SE Vic -chance event?

APLC & ABARE 2005

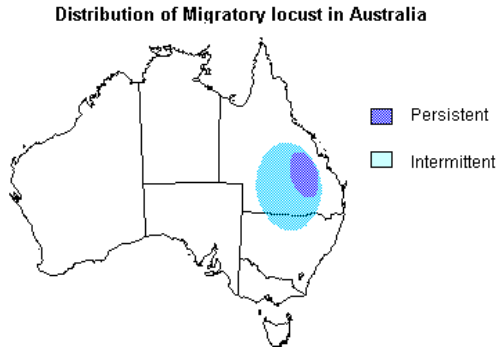



# Australia's other locusts

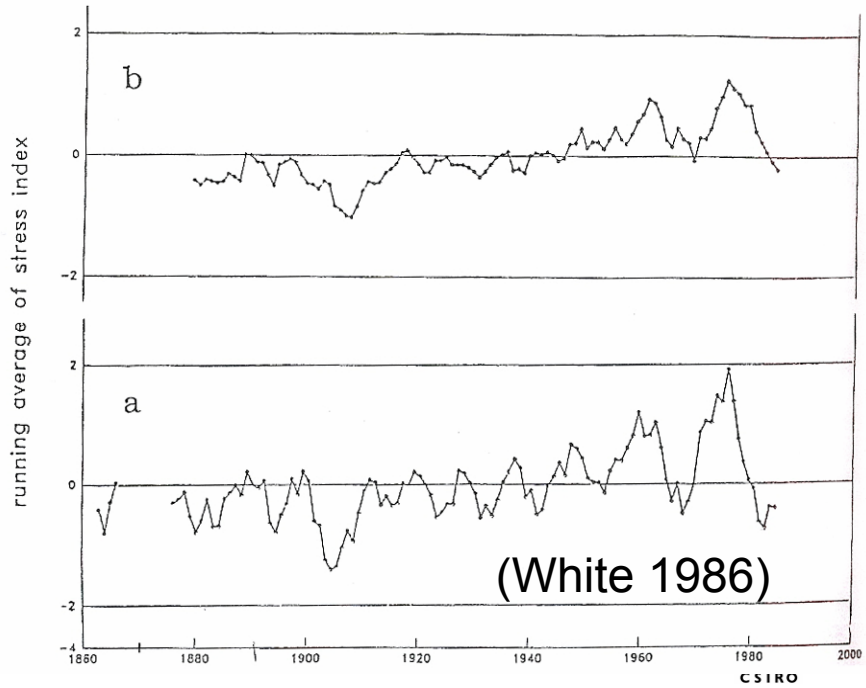
- Outbreaks other spp. poorly monitored & recorded.
- Migratory locust passes winter diapause in Central QLD. Persistent rainfall leads to migratory phase
- Locust spp. outbreak statistics linked to seasonal rainfall may show increaser/indicator species under CC



# *Eucalyptus* dieback

- Dieback of canopy trees
- Multiple situations– multiple causes
- Driven by tree stress – multiple factors - high soil nutrients, soil moisture extremes, salinity…
- Insect herbivory +ve feedback to death
  - defoliation – N rich regrowth – ▲ defoliation
- Fungal infection (e.g. *Phytophthora* sp.) another cause/symptom
- Increased extreme rainfall patterns induce tree stress levels?



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# Specialists - 40-50% of insect herbivores

## Species interdependencies

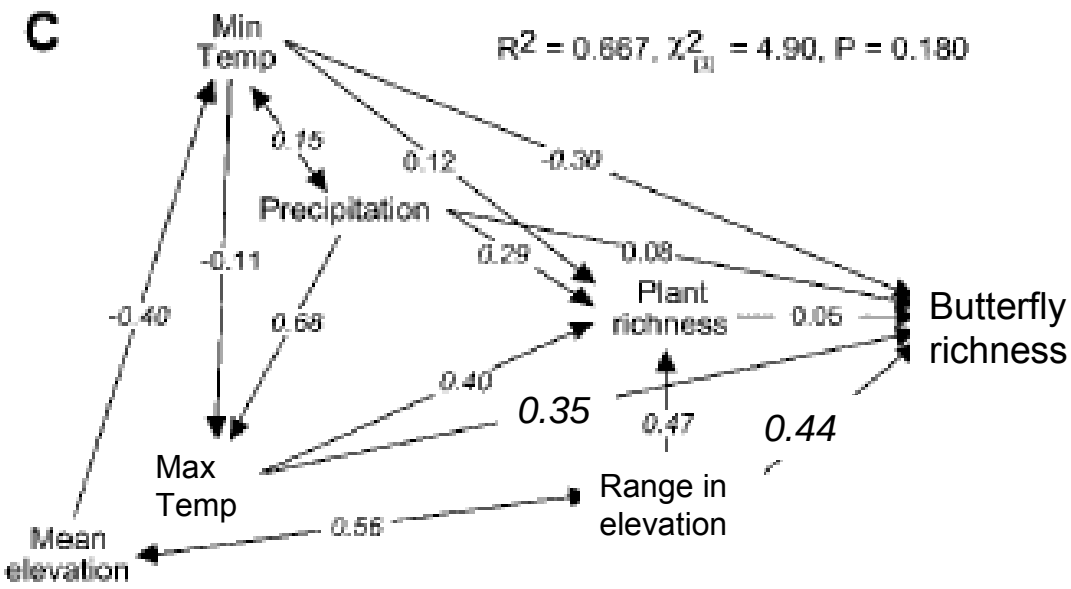
- Insects-plant co-radiation through increasing specificity a key driver of global species diversity (Novotny et al. 2006)
- Interactions allow plant diversity & community function – competition, reproduction & dispersal

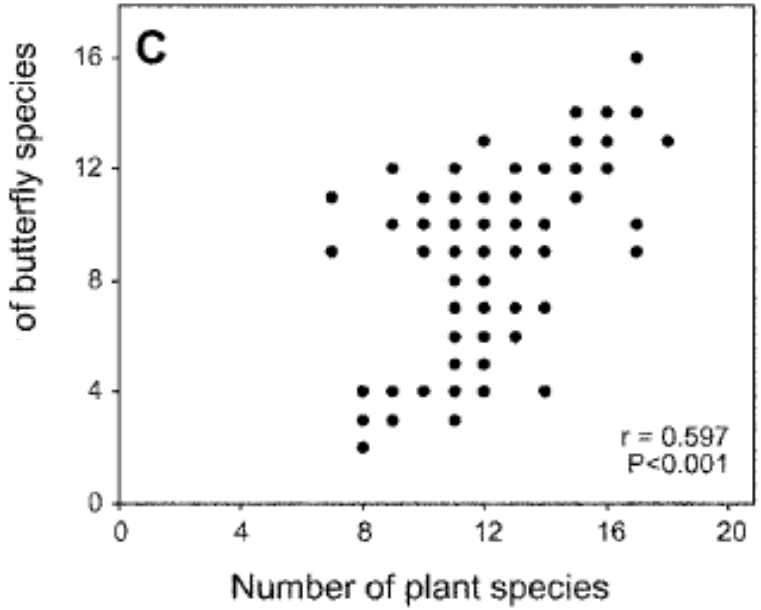
## Environmental tolerances

- Insect – plant dependencies vulnerable to de-coupling by CC
- Complex life history requirements & tight phenological synchrony to host plants (photoperiod v day-degrees)
- Extinction
  - Host loss > poor CC adaptation potential?
  - Already occurred in geological time (Labandeira et al. 2002)
  - Most critically endangered – those at limit of the host's physiological range
  - butterflies with complex life histories have narrowest climate ranges

# Specialists: environment-driven distributions

## Environmental factors key drivers of specialist insect biodiversity




(Hawkins & Porter, Am Nat, 2003)

# Specialist performance under CC

Reduced performance under ▲CO2 x ▲°C

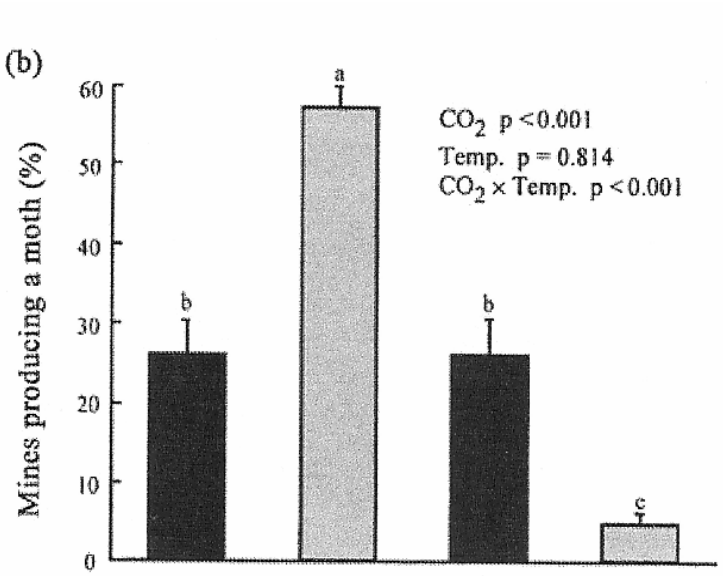
- Endophagous species the worst affected

▼ generation time

▲mortality – C:N food quality require higher consumption rates

▼biomass

(Johns & Hughes 2002)



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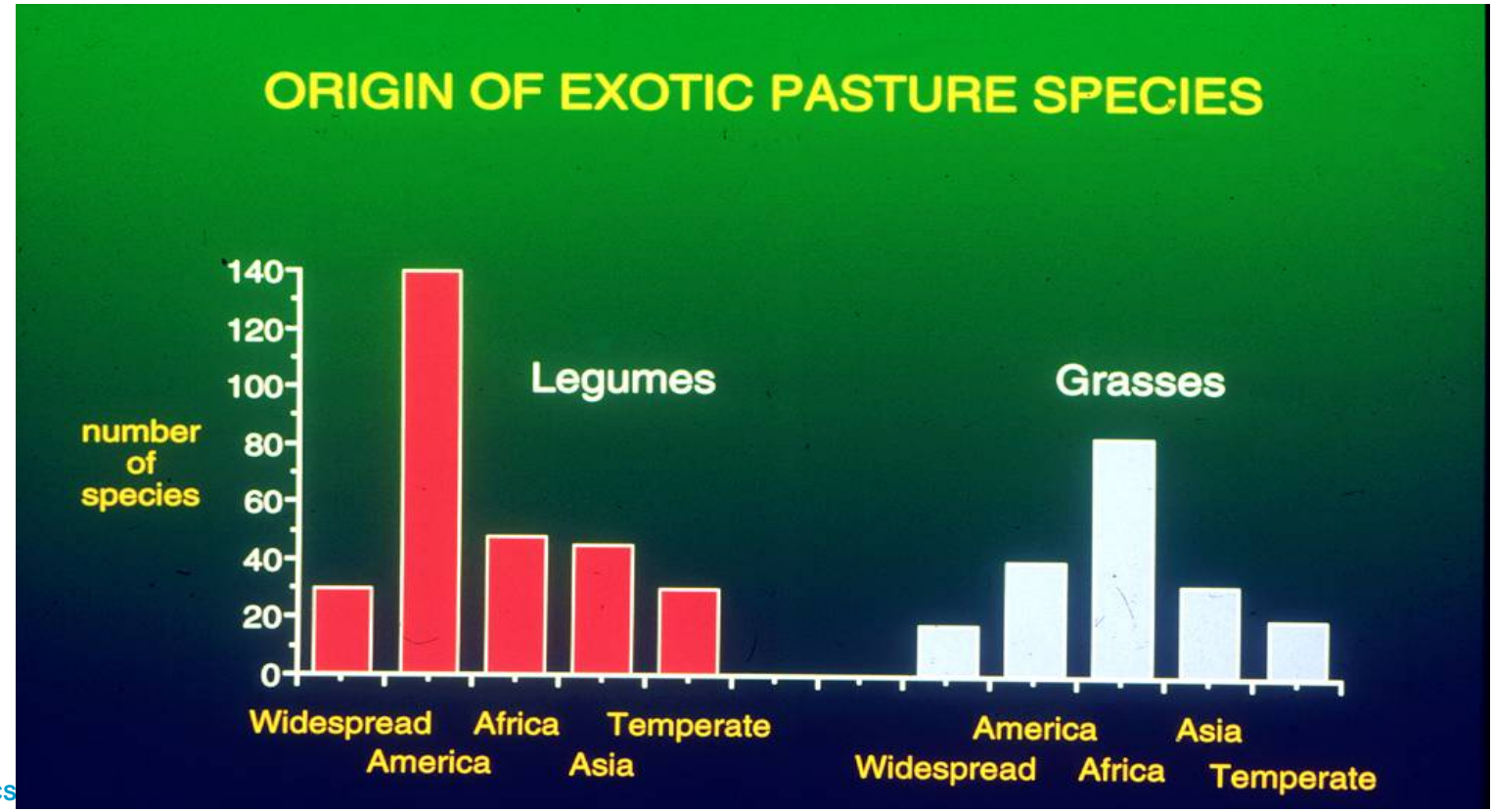
# Key transformer weeds & vertebrate grazing

- Shrubby legumes (most deliberate for forage/shade)
- Tropical pasture grasses (most deliberate for grazing)



# Vertebrate-driven plant invasions : perennial pasture grasses

- Naturalised introductions (463 spp)
- Transform fire regimes
- Buffel grass – runs down nutrients, changes fire regimes, invasive varieties
- Gamba grass – poor fodder when rank worst dry land grass, smothers, hot fires.
- 60+ weedy spp. & 400 sleeper spp. that can spread & degrade native grazed communities

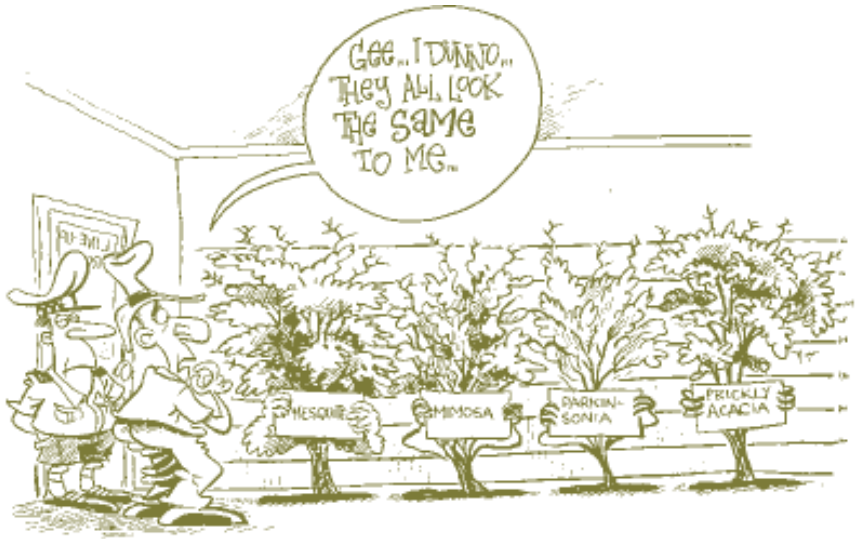
| | Useful | Non useful |
|---|---|---|
| Weedy | 17 | 43 |
| Non-Weedy | 4 | 399 |

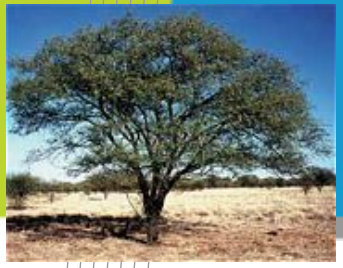
(Lonsdale 1994)

# Vertebrate-driven plant invasions : Leguminous shrubs

- Naturalised introductions (290 spp.)
- *Acacia, Senna, Parkinsonia, Prosopis, Sesbania, Mimosa, Leucaena* – 24 noxious species
- Transform soil fertility & acidification
- *Mimosa pigra* – spread driven by feral water buffalo
  - competition-free microsites & seed spread,
- 5 exotic *Acacia* sleeper species in Australia

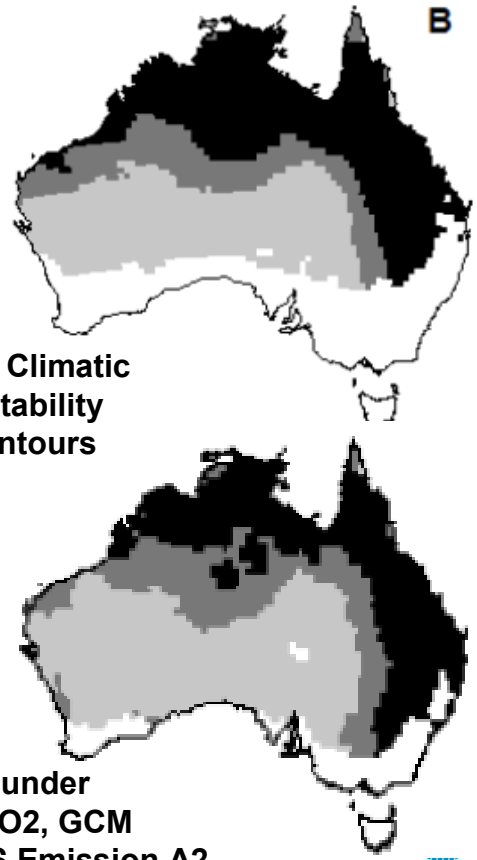
Paynter et al. 2003





# *Acacia nilotica* : Prickly acacia


- Legume shrub can invade 7M ha of key ecosystems under grazing e.g. Mitchell grasslands
- Spread through cattle browsing seed pods and vectoring seed to clean areas
- High recruitment and thickets next to watering-points where cattle congregate
- Uneven invasion patterns linked to soil moisture likely to be reactive to climate.
- Distribution likely to increase under CC
- Invade W into xeric sites -▲ water-use efficiency ▲$CO_2$
- ▲°C = ▲ reproductive to South.




Kriticos et al. 2006

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# Research priorities – some already defined!

## Biodiversity conservation research in a changing climate *Hilbert et al*. March 07

### SPECIES LEVEL Experiments

- Impacts of ▲°C x ▼$H_20$ x ▲$CO_2$ indirectly on plant-herbivore interactions and implications for community dynamics?
- Grazing driven Invasive-native species interactions (invasibility) under CC
- Does productivity in grazed communities drive vulnerability/resilience to CC?

### ECOSYSTEM LEVEL Observations

- Identify model systems for monitoring CC impacts
  - species (e.g. kelp watch, spreading & sleeper pasture weeds),
  - habitats (e.g. pristine, fire dependent, flood prone, boundary zones),
  - communities (e.g. Mitchell grasslands),
  - LTER's (e.g. Alpine grazing exclosures) &
  - databases (virtual herbarium)
- GIS maps (vegetation types, land use, soils, biodiversity inventories, invasive species distributions) to monitor & predict CC effects on species interactions

# My general questions

- Should the basic goals of vegetation conservation change given the realities of CC?
- Are current conservation strategies sensible strategies under CC? (e.g. water remote refugia; Landsberg et al. 2003)
- How will feral herbivore dynamics change grazing pressures under climate change?
  (e.g. Rabbit-RCD, or Donkey's in a wetter Kimberly's)
- How will specific insect-plant interactions drive adaptation versus extinction in insect herbivore communities under CC? (e.g. in weed biocontrol systems)
- How will insect herbivore communities restructure in response to ▲°C x ▼$H_20$ x ▲$CO_2$ ?
  (e.g. Open top/poly tube experiments simple herbivore food-webs of specialists (chewers) & generalists (suckers))

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