NSW Forest Monitoring and Improvement Program

Project 2: Baselines, drivers and trends for species occupancy and distribution

Rod Kavanagh, Brad Law, Nick Reid

Acknowledgement of Country

We would like to acknowledge all the Traditional Owners of the Country where we are zooming in from today, wherever you might be, and pay our respects to Elders, past, present and emerging. We would like to extend that respect to any Indigenous brothers and sisters in the meeting with us today.

Pictured: **Warwick Keen** “Always was, always will be” 2008
Gifted by the artist to UNE in 2008

Outline of presentation

1. Historical context
2. What we did
3. What we found
   I. Flora results
      - Disturbance impacts and case study (Orange-blossom orchid), fire responses, preliminary climate projections
   II. Fauna results
      - Case studies (Greater Glider, Powerful owl, Koala), 1990s median species occupancy examples
   III. Overview of findings
   IV. Collation of fauna trend data post-2000
   V. Power analyses
4. Some of the challenges
5. Opportunities going forward
6. What should happen next

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Historical context

1. Significant changes to forest management since the 1990s to improve conservation outcomes (RFAs):
   i. Large areas of state forest (SF) converted to national park
   ii. Formal adoption of harvesting rule set throughout SFs (i.e. Integrated Forestry Operations Approvals [IFOA] licence)

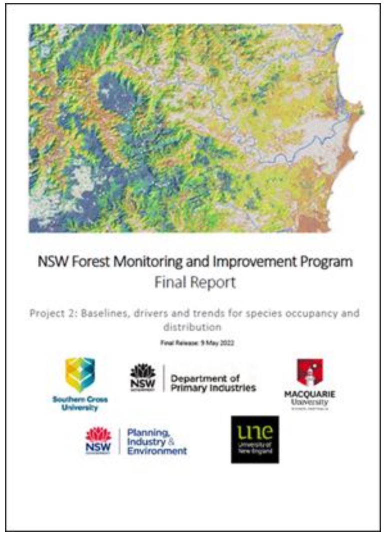
2. NSW government has introduced two compatible but distinct species monitoring programs, coordinated by NRC
   i. Forest Monitoring & Improvement Program (FMIP, cross-tenure)
   ii. Coastal IFOA (CIFOA, SFs only)

3. FMIP and CIFOA species monitoring programs provide first opportunity to evaluate conservation effectiveness of these significant changes

What we did – 1. A conceptual model of eucalypt forests

- Summarised knowledge about key properties, dynamics and disturbances that structure eucalypt-dominated forests in eastern NSW

- Broad forest and woodland formations – structural and floristic types – are determined by abiotic environment and disturbance history:
  - temperature
  - precipitation
  - soil fertility
  - topographic position
  - fire regime
  - timber harvesting



- Additional disturbance variables affect species distributions:
  - biotic
    - e.g. predation by cats and foxes
  - abiotic
    - e.g. increase in heatwaves due to climate change
    - or destructive influence of severe drought followed by extreme fire

What we did – Structural states or condition classes

- Six forest structural states or condition classes in eastern NSW forests and woodlands:
  1. Old-growth forest (extensive)
  2. Old-growth forest patches in riparian strips/protected areas in largely regrowth forest
  3. Old regrowth forest following timber harvesting or fire
  4. Young regrowth following timber harvesting or fire and planted native forest
  5. Woodland (similar to old-growth forest, but canopy cover < 30%)
  6. Disturbed woodland following partial clearing, logging, fire or grazing

- Fire (frequency and severity) and timber harvesting are main factors responsible for transitioning from one condition class to another
  - Each supports a characteristic assemblage of fauna and flora

What we did – 2. Identified priority fauna species

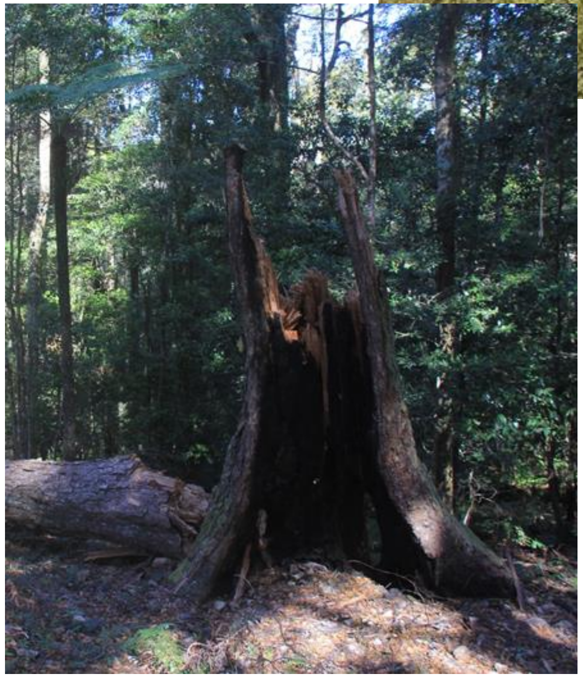
- Priority **fauna** species were chosen based on:
  1. Forest-dependent (e.g. hollow-dependent)
  2. Taxonomic class and functional group representation
  3. Sensitive to intensive logging
  4. ‘Critical weight range’ (sensitive to introduced predators)
  5. Sensitive to climate change
  6. ‘Threatened’ (NSW *Biodiversity Conservation Act 2016*)
  7. NSW ‘Saving Our Species’ modelling priority
  8. Species is a key threatening process due to impacts on other species
  9. Detectable using cameras, song meters or bat-call detectors

- 140 priority fauna species consisted of 53 mammals, 37 birds, 32 reptiles and 18 frogs

- Abbreviated list of 31 mammals & birds (1 frog):
  - sufficient data for species occupancy modelling
  - detectable using cameras, song meters or bat-call detectors

… and priority flora species

- 191 Priority **flora** species were chosen based on:
  - Analysis of native species widespread in eastern NSW forests, from a range of life-forms, and likely responsive to:
    1. Forest harvest operations (cf. old-growth) (12 species)
    2. Fire (40)
    3. Climate change (89)
  - Introduced species capable of causing significant forest ecosystem change:
    4. Weeds (11, 2 subspecies)
  - Native species most sensitive to:
    5. Root-rot Fungus (*Phytophthora cinnamomi*) (42)
    6. Myrtle Rust (*Austropuccinia psidii*) (17)



What we did – 3. Data and approach

- Assembled multidisciplinary team
- Recovered historical fauna data sets from 1990s:
  - Forest EISs, NEFBS, CRA (1991–1998)
    - **5719 systematically surveyed fauna sites**
  - Compiled records of:
    - **520 native vertebrate species** (mammals, birds, reptiles, amphibians)
    - **11 introduced mammal species**
- Accessed historical systematic flora survey data in BioNet for baseline period (1987–2000)
  - **Systematic flora surveys of** state forests, national parks and nature reserves – **5248 flora sites**
    - **2808 native vascular plant species** (58% of NSW flora)
    - **327 introduced plant species**

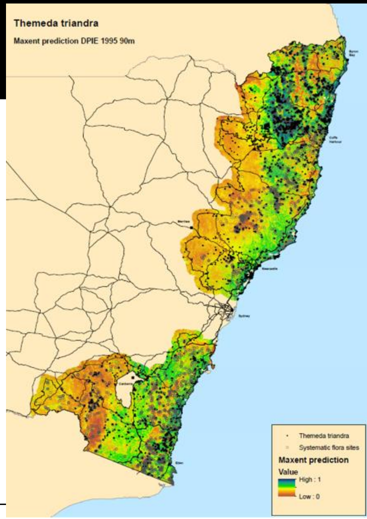
Explanatory covariate data

- For following RFA regions:
  - North East (Upper NE and Lower NE)
  - Southern
  - Eden

- We sourced numerous relevant spatio-temporal environmental (covariate) data from 1990s:
  - Climatic
    - e.g. Radiation, several Temperature and Precipitation variables, Evapotranspiration, Available water
  - Several topographic indices including Distance to streams
  - Vegetation type (Keith formations)
  - NDVI and soil variables (sand, silt and clay contents)
  - Tenure
  - Candidate old growth (surrogate for timber harvesting)
  - Fire (number of fires, time since last fire)
  - But not:
    - feral predators (cats and foxes) *
    - feral and overabundant native herbivores *
    - introduced pathogens (Myrtle Rust, Phytophthora) *
  - * No 1990s baseline data for analysis

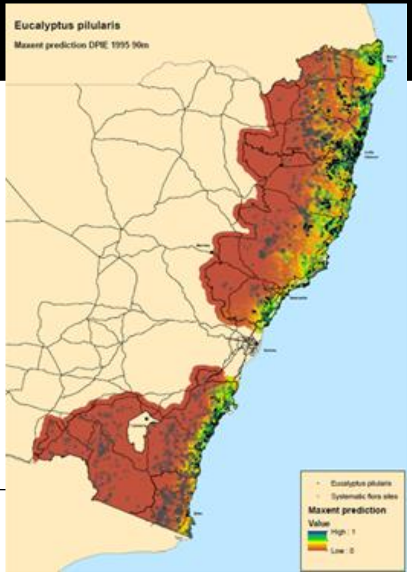
- Developed framework of analytical techniques:
  - Species occupancy modelling for fauna
  - Generalised additive modelling and binomial occurrence analysis for flora
  - … and for both fauna and flora:
    - Environmental niche modelling (Maxent)
    - Climate forecasting
    - Survey gap analysis
    - Power analysis

What we did – 4. Modelling species occupancy and habitat suitability



- Survey gap analyses for:
  - Baseline systematic fauna data set
  - Baseline systematic flora data set
  - Contemporary WildCount program
- Naïve occupancy estimates
- Baseline (1990s) species modelling
  - Species occupancy modelling (SOM) fauna:
    - 28 priority species in North East
    - 16 priority species in Southern/Eden
  - Environmental niche (‘species distribution’) modelling (ENM) – Maxent
    - 446 fauna species models
    - 174 priority flora species and model ‘stacking’
  - ENM – Boosted Regression Tree
    - 362 species – survey method models attempted
    - 286 models achieved
- Contemporary fauna occupancy estimates
  - Re-analysis of WildCount results (2012–2016)

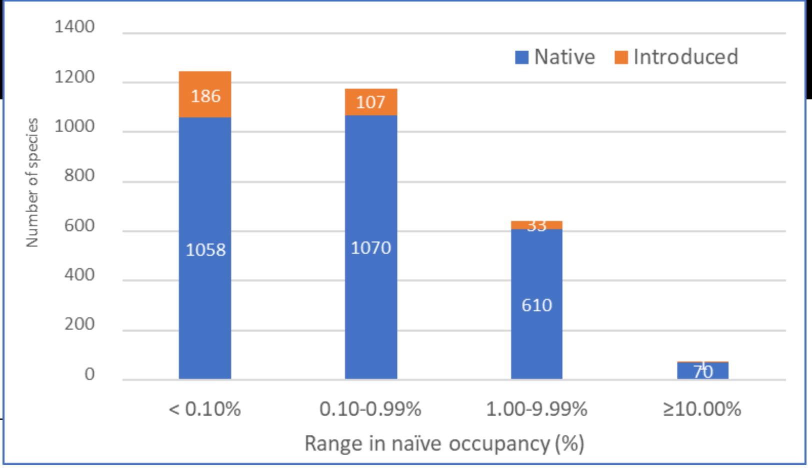
What we did – modelling fauna occupancy trends, survey power and climate projections

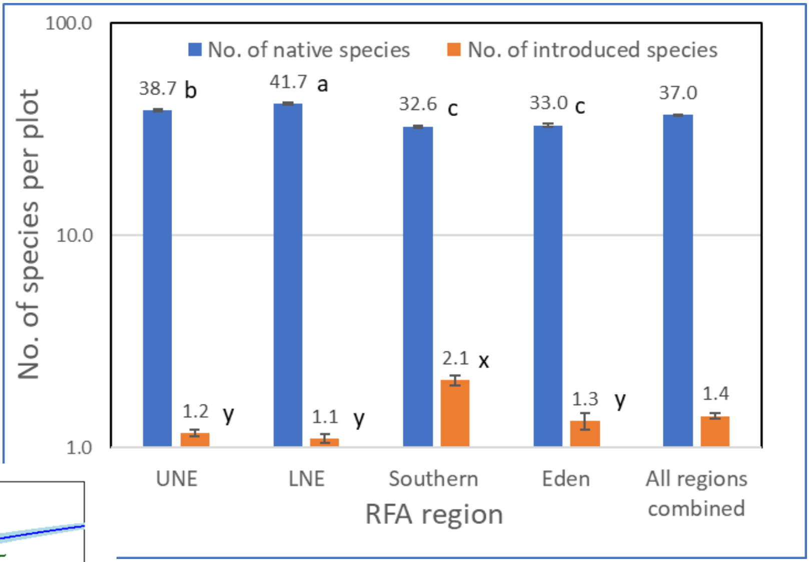


- Trend analyses – research data sets
  - Trends in various mammals, birds and a frog:
    - Eden – occupancy of 3 gliders, 3 possums, 2 owls, 1 nightjar
    - Chaelundi – occupancy and calling activity of 1 frog
    - North East hinterland forests – Koala occupancy
    - Northern NSW plantations – occupancy of 4 arboreal marsupials, 3 nocturnal birds
    - Eden – Southern Brown Bandicoot occupancy
    - Bago-Maragle – Yellow-bellied Glider occupancy
    - Ourimbah and Upsalls Creek – 2 bats
- Power analysis
  - Generalised curves predicting required number of survey sites
  - Based on equations of Guillera-Arroita & Lahoz-Monfort (2012)
- Preliminary climate projections
  - 7 Priority fauna species
    - 3 forest owls, Greater Glider, Rufous Scrub-bird, Rufous Bettong, Stuttering Frog from SOS ‘Persistence in the Landscape Project’ (PLP)
  - 81 Climate-sensitive priority flora species

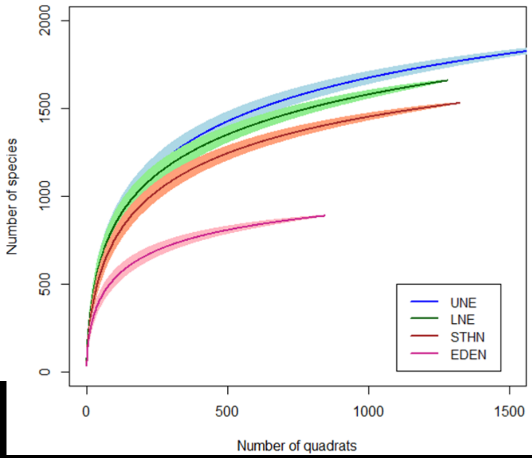
What we found – 1. Flora results

- 2617 Native species recorded in 4811 forest plots
- Most species (76%) were infrequent or rare
  - 407 species recorded in only 1 plot
  - 38% had naïve occupancy (sample frequency) < 0.1%
  - 76% had naïve occupancy < 1%
  - only 2% occurred in ≥ 10% of plots
- Most introduced species (n = 327) were even scarcer
- Native plants were more species-rich in northern than forests than southern, both at plot and regional scale
- But introduced species were more diverse in southern region





▲ Native and introduced species richness per plot by RFA region



◀ Species accumulation curves for native flora species by RFA region

What we found – 2. Disturbance impacts

- Impacts of timber harvesting on flora species in eastern NSW eucalypt forest
  - No accurate spatio-temporal information about timber harvesting to 2000 was available
  - We used ‘Candidate Old Growth’ (COG) forest data layer developed by CRA in 1990s – as a surrogate for (reciprocal of) timber harvesting
  - Problems with COG
    - mapping was never validated
    - includes areas that do not meet definition of old-growth forest, and areas where timber harvesting had occurred
    - main value indicates areas where ≥ 10% of forest canopy included senescent trees and ≤ 10% even-aged regrowth (in mid 1990s)
    - caution needed in interpreting results

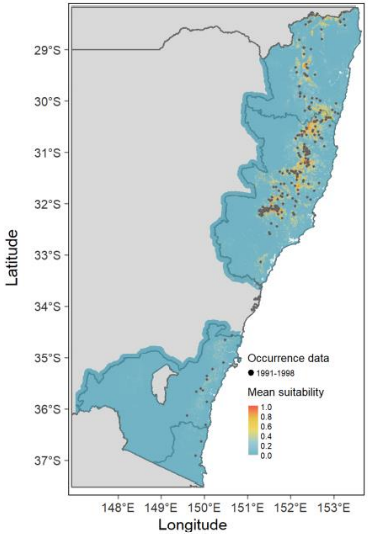
- Very few native plant species associated with COG
  - i.e. very few species’ occurrence appeared to affected by timber harvesting up to year 2000
  - 9 rainforest and wet sclerophyll species, including 3 epiphytes, likely sensitive to timber harvesting.
  - most epiphytes likely to decline in logged wet sclerophyll forest for some decades
    - due to loss of large habitat trees

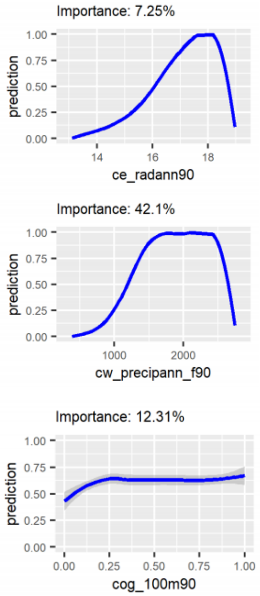
COG ('logging') response of native flora species from Generalised Additive Modelling

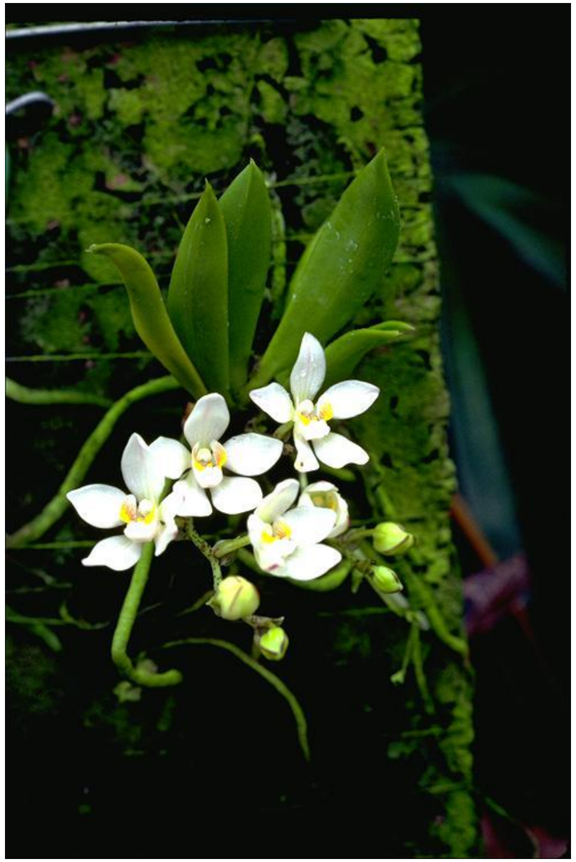
RFA Region	COG	Not COG	(n)
UNE	16 (6%)	24 (9%)	272
LNE	2 (1%)	8 (4%)	223
Southern	8 (4%)	12 (6%)	213
Eden	2 (1%)	10 (6%)	158

Case study – Orange-blossom Orchid (*Sarcochilus falcatus*) – likely sensitive to timber harvesting

- Semi-pendent epiphyte occurs on rainforest and Blackwood (*Acacia melanoxylon*) trees in rainforests and wet sclerophyll forests at higher elevation
    - 92% Greater naïve occupancy (NO) in unlogged plots than across all LNE sclerophyll forest plots
    - Also greater occurrence in unburnt than burnt forests throughout North East
        - LNE naïve occupancy (NO) = 0.064
        - UNE NO = 0.014
        - Southern NO = 0.004
        - Eden NO = 0.000
    - ENM: species prefers high-rainfall, well-insolated, high-productivity forests with marked seasonal temperature differential, as well as old-growth (unlogged) forest
        - Test AUC = 0.93
    - Despite high detectability, low NO means that monitoring program requires 1,785 sites to detect 30% decline over 10 years with 80% likelihood







What we found – 3. Fire responses

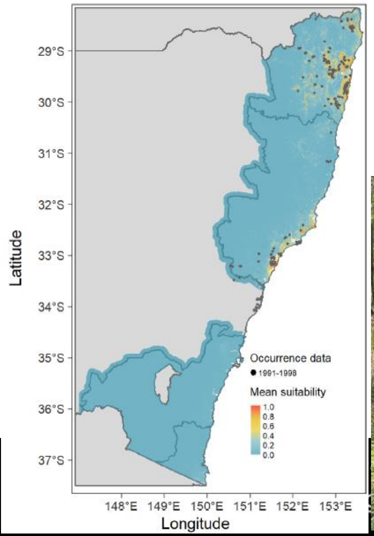
- Many native plant species were responsive to fire
  - Up to 50% of frequent species in each RFA region were associated with either recent fire (in last 30 years), or lack thereof
  - Not surprising given prevalence of fire in landscape and role of fire in determining distribution of sclerophyll forest vs rainforest on both historic and evolutionary time-scales
  - Patterns as expected:
    - sclerophyllous species were usually associated with recent fire (last 30 years)
    - rainforest (and wet sclerophyll) species were usually associated with lack of recent fire
    - but a few sclerophyllous species associated with lack of recent fire (particularly ‘seeder’ species)
    - a few wet sclerophyll species associated with recent fire
    - some species’ responses varied among regions (e.g. north vs. south)

Fire response of native flora species from Generalised Additive Modelling (GAM)

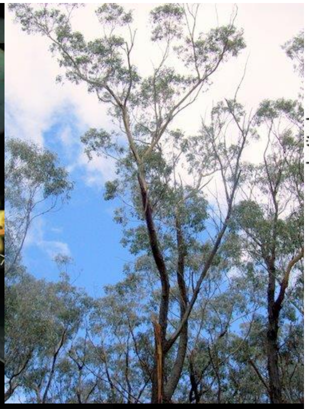
RFA Region	Unburnt	Burnt	(n)
UNE	76 (25%)	64 (21%)	304
LNE	55 (21%)	28 (11%)	259
Southern	44 (20%)	28 (13%)	221
Eden	47 (29%)	30 (19%)	160

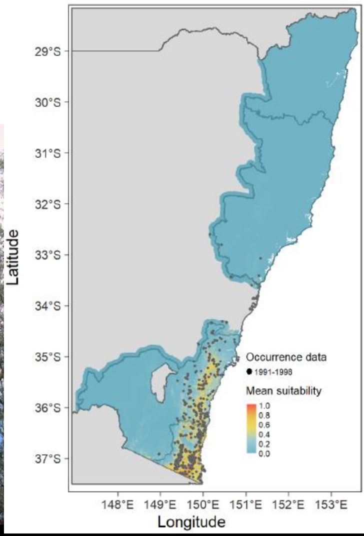
Examples of dry sclerophyll species fire responses

- Grass tree (*Xanthorrhoea latifolia*)
  - Locally common in shrubby dry sclerophyll forests, usually on sandy soils of low fertility
  - More frequent in frequently burnt areas, relative to areas unburnt for >30 years, in UNE
    - UNE: 10.1% vs 3.4% *
  - More frequent in undisturbed (COG) than disturbed (non-COG) areas:
    - UNE: 7.3% vs 5.4% *
    - but artefact of habitat unsuitable for logging rather than sensitivity to timber harvesting



- Silvertop ash (*Eucalyptus sieberi*)
  - Stand-dominant canopy tree in dry forest on ridges and upper slopes in Eden region
  - More frequent in more recently or frequently burnt areas in Southern and Eden, relative to unburnt
    - Southern: 20.4% vs. 7.3% (GAM ***)
    - Eden: 42.5% vs 16.5% (GAM ***)
  - Less frequent in undisturbed (COG) than disturbed (non-COG) areas in Eden
    - Eden: 27.4% vs 33.6% *





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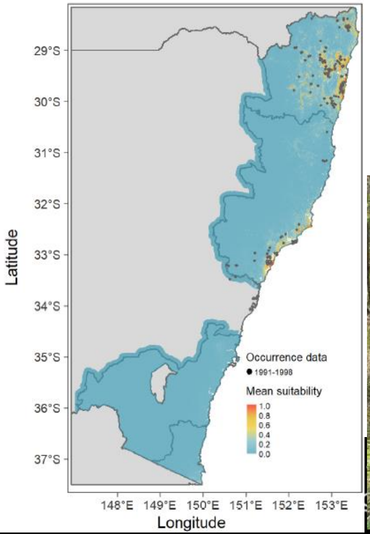

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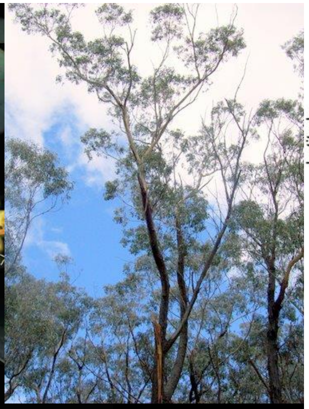
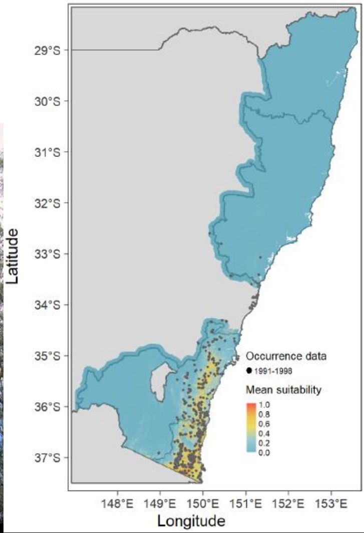
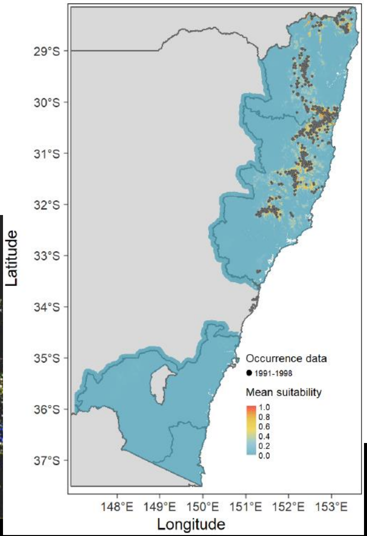


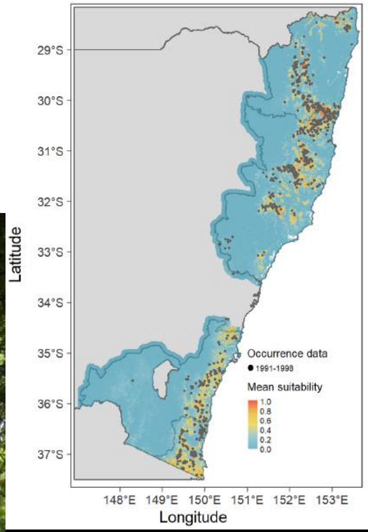


Examples of rainforest and wet sclerophyll fire responses

- Soft corkwood (*Ackama* [*Caldcluvia*] *paniculosa*)
  - Medium-sized pioneer tree common on rainforest margins and in wet sclerophyll forest
  - More frequent in unburnt vs. recently burnt areas
    - UNE: 11.4% vs 3.6% *
    - LNE: 21.3% vs 10.7% *
  - Also more frequent in disturbed (non-COG) than undisturbed (COG) areas:
    - UNE: 7.3% vs 5.4% *

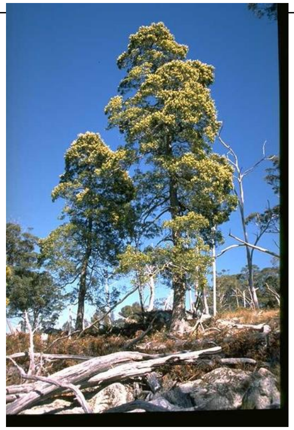


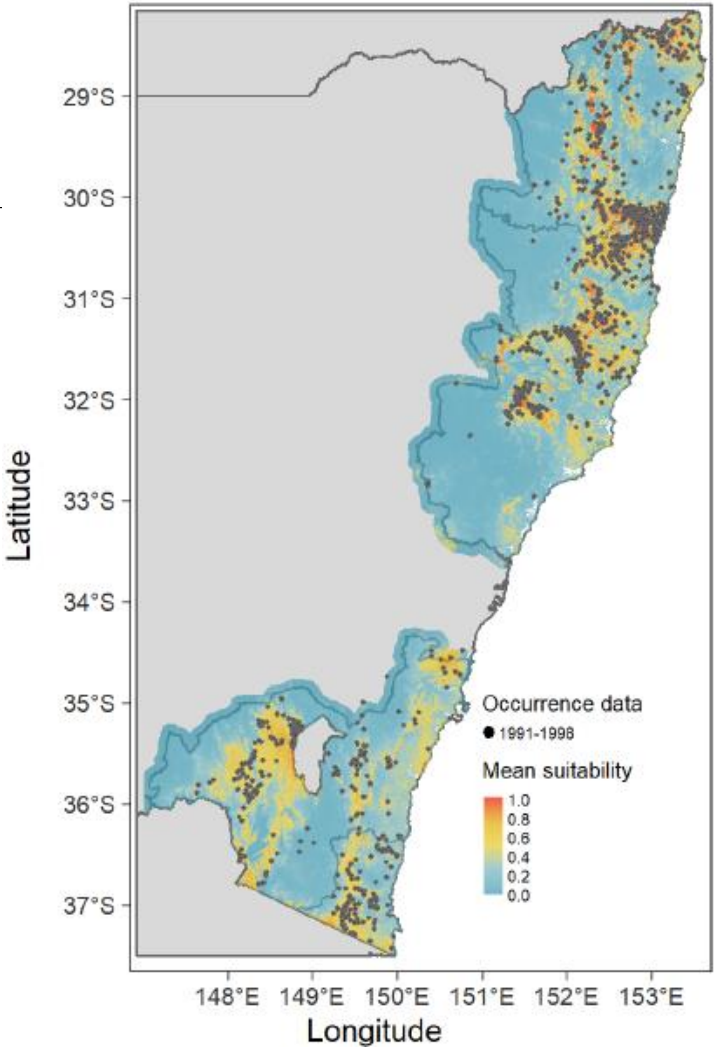
- Rough tree fern (*Cyathea australis*)
  - Widespread in rainforest and open forest in moist shady situations
  - Less frequent in unburnt vs recently burnt areas
    - Eden: 7.8% vs 13.7% **
  - Also more frequent in disturbed (non-COG) than undisturbed (COG) areas in UNE
    - UNE: 10.3% vs 8.4% *



Other plant fire responses

- Blackwood (*Acacia melanoxylon*)
  - Widespread small to medium forest tree, mainly wet sclerophyll forest and vicinity of cooler rainforests
  - More frequent in areas unburnt for >30 years relative to more recently burnt classes
    - UNE: 16.5% vs 9.6% *
    - LNE: 26.0% vs 14.5% *
    - Southern: 15.1% vs 6.8% *
  - a fire-dependent 'seeder' sp., but intolerant of frequent fire

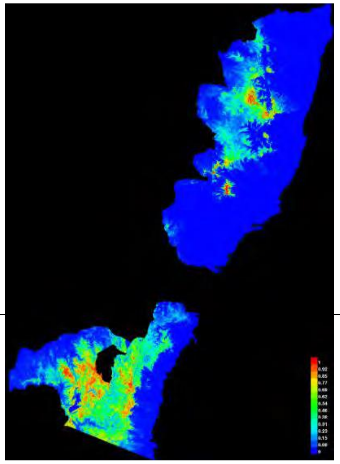


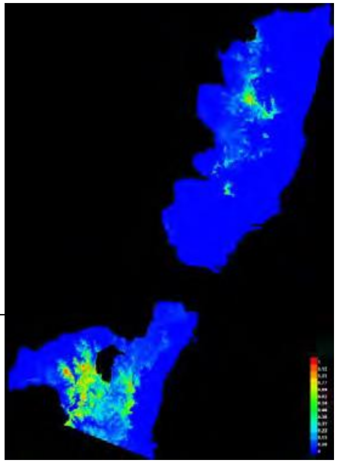


What we found – 4. Preliminary climate projections

- 81 Widespread climate-sensitive flora species identified
  - species occupying a narrow range in elevation, latitude, temperature or precipitation, and near upper or lower limits of these variables
  - least able to colonise other parts of landscape as climate changes in medium to longer term
- ENM (Maxent) models of 2000 habitat suitability projected to predicted 2070 climate (using MICROC3.2 GCM)
  - 59% of species will have less medium to high-suitability habitat by 2070 due to climate change
  - 37% will have more suitable habitat
- Likely best-case scenario

Eucalyptus pauciflora

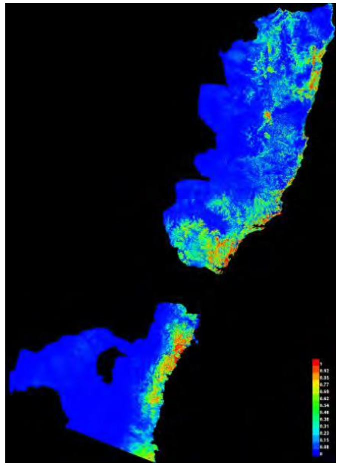


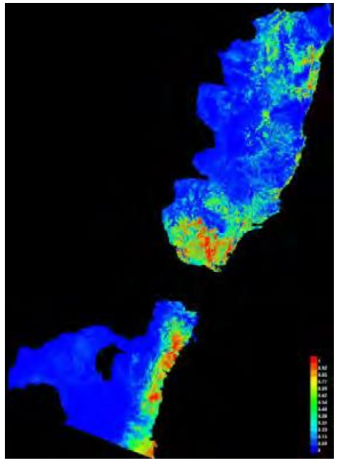


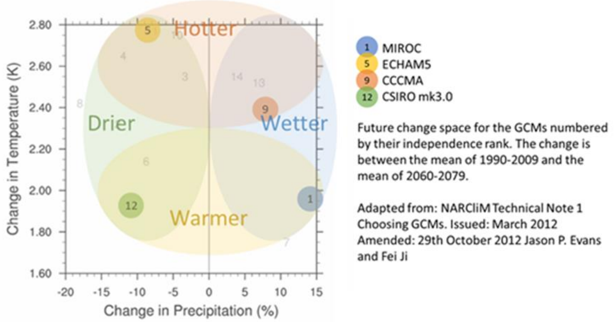
2000

2070

Gompholobium latifolium

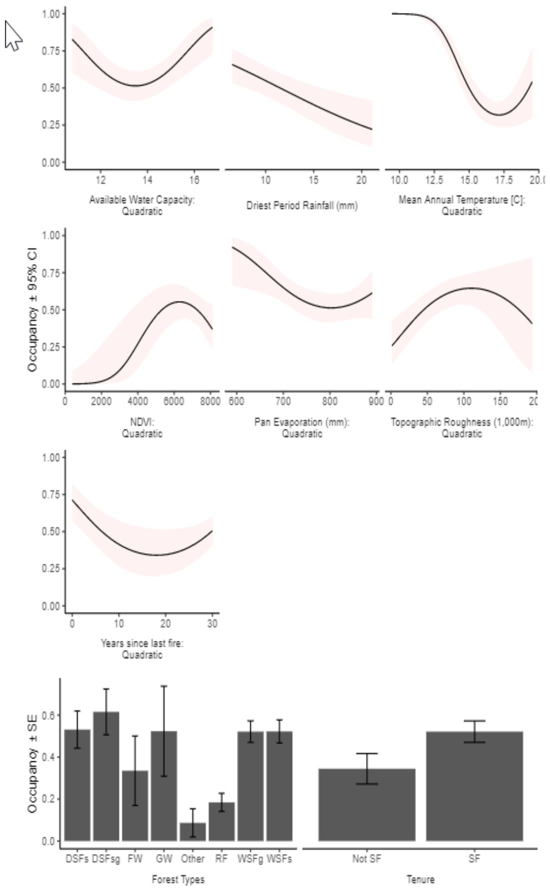


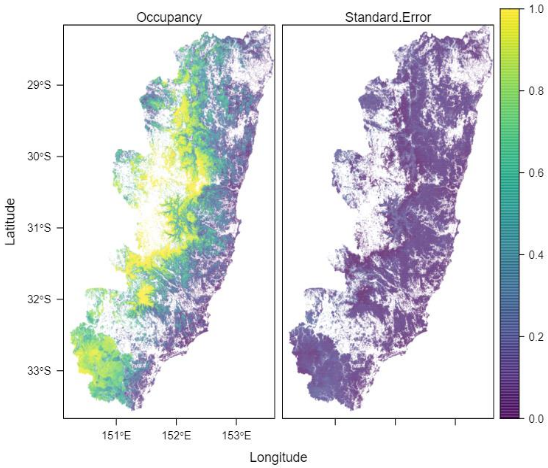




What we found – 5. Fauna results
Case study – Greater Glider (northern)

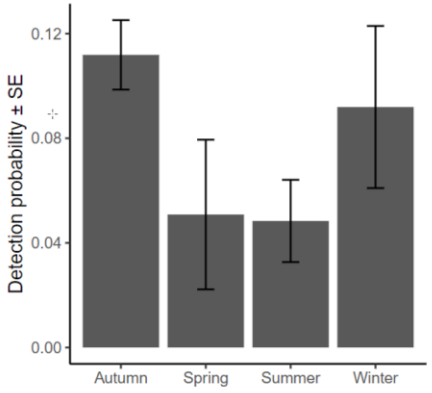
- Hollow-dependent species, requires large tree hollows and nutrient-rich foliage
- 814 detection sites and 1,286 non-detection sites
- Median detection probability was 0.753 ± 0.019 per visit
- Median occupancy probability was 0.52 ± 0.05
- Important drivers for occupancy:
  - Cooler temperatures (at high elevation)
  - Forest type
  - Years since Fire
  - Land tenure
- Logging history covariate needs improvement

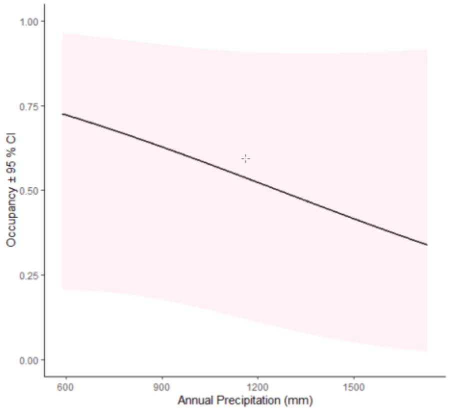


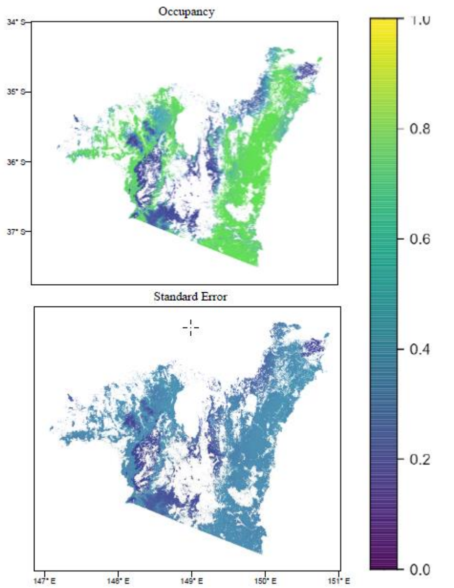


Case study – Powerful Owl (southern)

- Requires large tree hollows for nesting, top-order predator
- 83 detection sites and 652 non-detection sites
- More detectable in autumn/winter
- Median occupancy was 0.56±0.07
- Important drivers for occupancy:
  - Annual precipitation (negative)







Case study – Koala (northern)

- 84 detection sites and 2016 non-detection sites
- low detectability ~ 0.09 per night using listening, call playback and spotlighting
- 1990s baseline – imprecise occupancy = 27 ± 17% across the surveyed public forests in north-eastern NSW.
- 1990s baseline map - koalas widespread in 1990s (except most high elevations); broadly consistent with recent analyses.

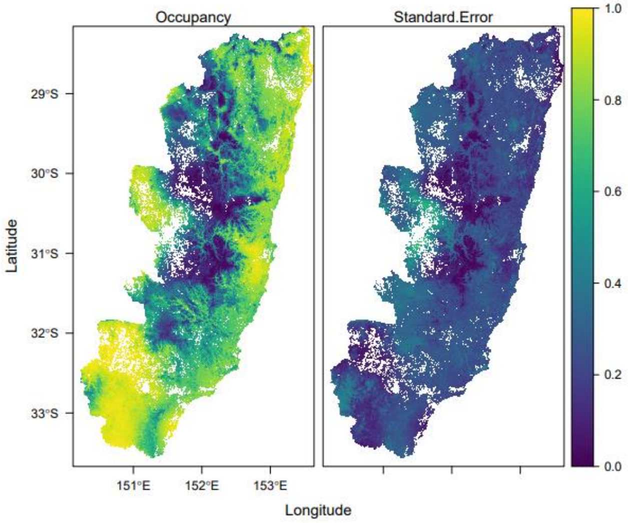


Figure 3: Occupancy and standard error maps

1990s Median Species Occupancy Examples (Table 25)

Occupancy modelling for only 28 fauna species

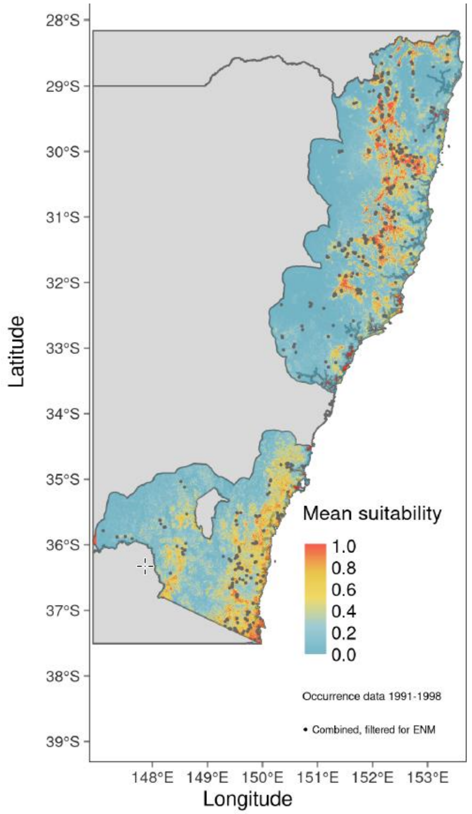
Scientific Name	Common Name	Region	Survey Method	Probability of detection	Probability of occupancy	Map reliability	Suitable for occupancy monitoring across region
Ninox strenua	Powerful Owl	Northern	NOCPB	0.16	0.56 ± 0.07	Good	Yes
Ninox strenua	Powerful Owl	Southern	NOCPB / Spotlighting	0.11	0.58 ± 0.26	Indicative	Yes
Petauroides volans	Greater Glider	Northern	NOCPB	0.75	0.52 ± 0.05	Good	Yes
Petauroides volans	Greater Glider	Southern	NOCPB / Spotlighting	0.51	0.62 ± 0.11	Good	Yes
Petaurus australis	Yellow-bellied Glider	Northern	NOCPB	0.34	0.39 ± 0.05	Good	Yes
Petaurus australis	Yellow-bellied Glider	Southern	NOCPB / Spotlighting	0.73	0.17 ± 0.05	Good	Yes
Tyto tenebricosa	Sooty Owl	Northern	NOCPB	0.13	0.68 ± 0.15	Good	Yes
Tyto tenebricosa	Sooty Owl	Southern	NOCPB / Spotlighting	0.01	0.13 ± 0.08	Good	Yes

What we found – overview of findings

- Timber harvesting and fire did not appear to be major drivers of occupancy or habitat suitability for most fauna species
    - caveat: quality of covariate layers could be improved
- Climatic drivers, particularly temperature, precipitation and related variables, were important covariates in SOMs and ENMS of most fauna and priority flora spp.
    - climate change expected to exacerbate fire frequency and severity
        - major determinant of future fauna and flora species occurrence and driver of change
    - climate change and fire represent the most significant threat to the biodiversity of the eastern NSW forests
        - but biota of eastern NSW eucalypt forests are dependent on periodic fire
        - identifying appropriate fire regimes and managing shifting fire mosaic to conserve plant and animal biodiversity is a major challenge

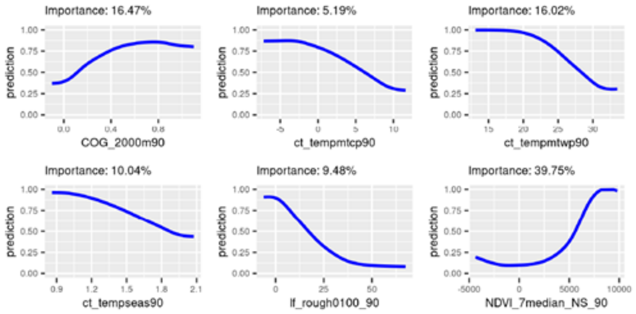
What we found

- SOMs provided most useful metrics for reporting status and trends of fauna
- SOM analysis requires that fauna survey methods include repeat visits to each site; this restricted number of species for which SOM could be undertaken
- ENMs were useful for modelling historical status and habitat suitability of fauna when data were inadequate for occupancy modelling
    - Maxent models of 444 of the 470 fauna taxa
    - Maxent models of 174 species of the 192 priority flora taxa



Maxent (environmental niche) model of **Southern Forest Bat:**

◀ habitat suitability (spatial prediction)

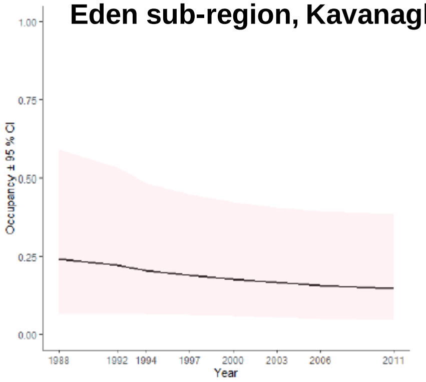


▲ habitat suitability in relation to most important environmental covariates

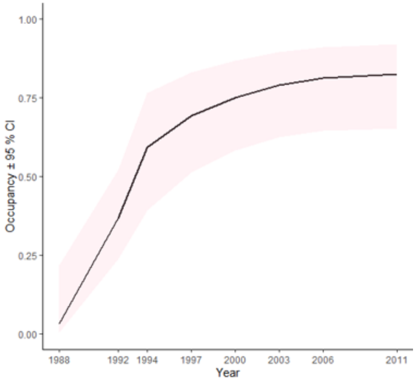
Collation of trend data post-2000 (examples)

- Very little trend data available – lack of long-tern monitoring, but some exceptions…
- Since 2000, trends in fauna occupancy or activity split evenly between species that remained stable or increased and species that declined
    - species in decline: Greater Glider (due to timber harvesting and fire)
    - species on increase: Sooty and Powerful Owls, Eden forests, 1988-2011
    - complex trends: Southern Brown Bandicoot S of Eden
    - Species stable: koala in hinterland forests of ne-NSW

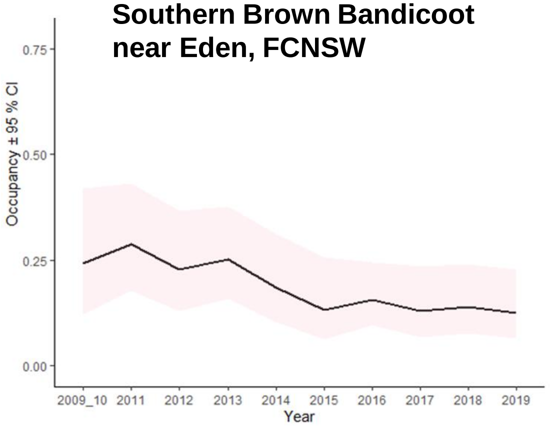
Greater Glider 1988–2011
Eden sub-region, Kavanagh



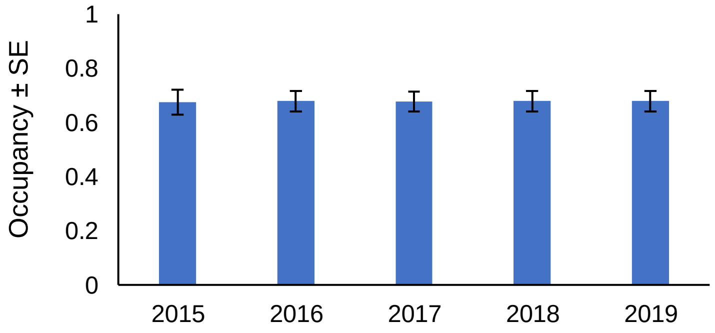
Sooty Owl 1988–2011
Eden sub-region, Kavanagh



Southern Brown Bandicoot
near Eden, FCNSW

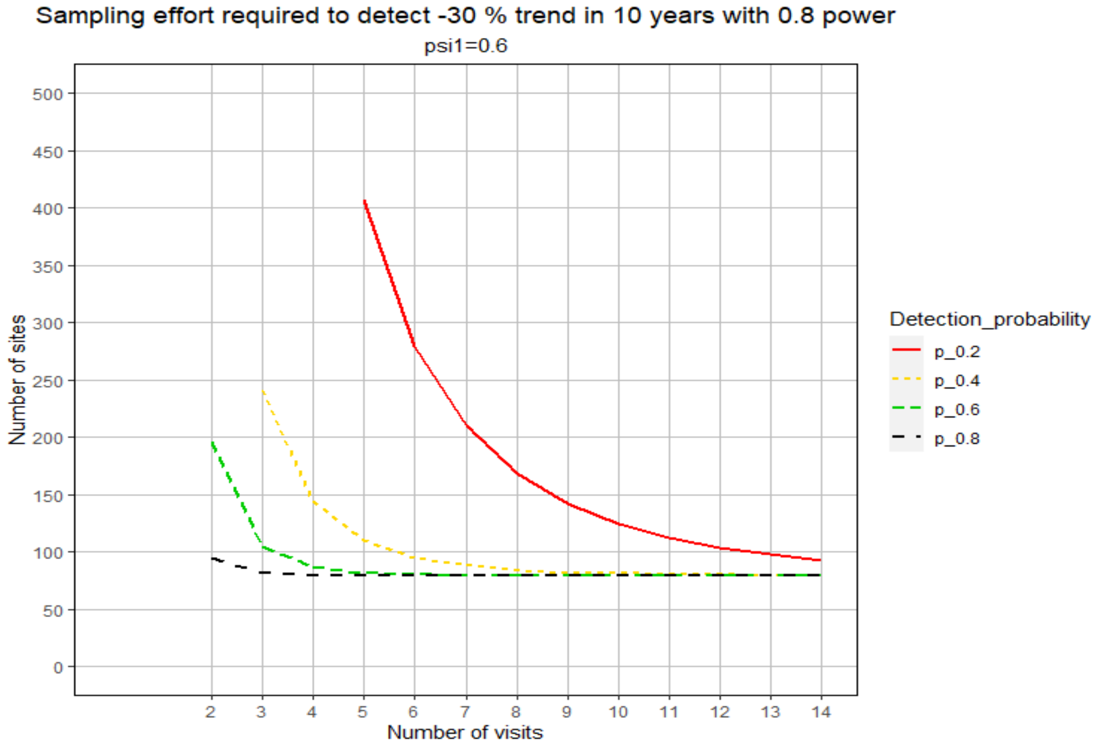


Koalas hinterland forests, north-east NSW, NSW DPI



Power analyses to inform design of monitoring programs

- Based on probability of detection and occupancy for a species we can calculate survey effort required for monitoring :
    - Greater gliders with spotlighting ~ 200 sites per year (2 visits)
    - Koala ~ 60 sites per year with acoustic monitoring (seven nights) in koala habitat to detect.
    - Survey effort curves can also be applied to new survey methods using probability of detection.



Some of the challenges

- Lack of repeat visits in most 1990s fauna systematic surveys
- Tenure bias toward public rather than private forest in all data sets
- Poor quality of environmental covariate data, especially disturbance history and threats
- Complexity and ambition of project
  - synthesising disparate expertise (e.g. occupancy modelling and environmental niche model projections)
  - large number of species
  - modelling across both space and time
  - inconsistent survey data by species
  - uncertainty in relation to climate projections
  - time constraints
- Difficulty accessing and massaging historical survey data into usable form
- Lack of systematic regional surveys since 1990s
  - lack of suitable trend data for almost all species

Opportunities going forward

- Modelling species occupancy for many more fauna species using data resurrected by project
- Ideally, modelling should use upgraded, or newly developed environmental covariate layers for:
  - significant disturbances (e.g. fire and logging)
  - additional threats (e.g. invasive species)
  - climate extremes
- New species monitoring programs can utilise 1990s baseline data to report against status of species before advent of major climate change and before black summer fires
  - this would fulfil intentions from 1990s IFOA harvesting licences to monitor forestry impacts in NSW forests on species over past 25 years
- Future surveys should utilise broader set of methods than just camera traps, song meters and ultrasonics (which do not detect all priority fauna species)
  - repeat surveys should be conducted over several days during each sampling period
  - power analysis and survey gap analysis should be utilised to optimise design of future monitoring plot networks
- WildCount (2012–16, 2017–21) camera-base survey program in national parks is an opportunity for FMIP and CIFOA to leverage off

What should happen next

- New survey technologies should be developed (e.g. call recognisers, image recognition) and calibrations made between new methods and methods used in 1990s
- New covariate layers are needed for modelling, including better:
  - disturbance histories (logging and fire severity)
  - density of large old hollow-bearing trees
  - occurrence or density of invasive species (e.g. introduced predators, herbivores, pathogens and domestic livestock grazing)
- Forest monitoring should begin as soon as possible, especially of priority species, including those most at risk from climate and fire regime changes
- Adequate and ongoing resourcing should be ensured to provide continuous data streams and best-practice data management, analysis and reporting mechanisms
- Historical species models (SOM and ENM) should be expanded for more common species that may decline due to climate change or other threats in future
- Modelling effort should include an expanded set of climate projections
- Finally, FMIP and CIFOA designs should be integrated
  - CIFOA can be designed to serve both surveillance monitoring purposes and answer questions about land management impacts using an adaptive management framework

Questions

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