ACT Government

Environment and Sustainable Development

Project Plan:

Kangaroos and Conservation - Researching the relationships between kangaroo density, herbage mass, pasture floristics and reptile diversity in grassy ecosystems around Canberra.

Aims

1. To provide management advice based on quantitative empirical assessments to guide the management of grazing pressure, particularly from kangaroos, in lowland grassland and grassy woodland areas of conservation value. The advice by Morellet *et al*. (2007) for monitoring vegetation-herbivore systems is favoured, namely that the measurements should include abundance of large herbivores, indicators of herbivore performance, indicators of grazing pressure, and indicators of grazing impact such as change in biodiversity;

2. To facilitate aim 1 by improving the knowledge base for management of local grazing systems by developing a kangaroo numerical response empirically from annual records of green herbage mass and kangaroo population growth rates, and placing the result into the existing ACT population model of kangaroos, vegetation and management treatments; and

3. To monitor the condition of representative lowland native grassland and woodland sites in the ACT in relation to kangaroo grazing pressure, particularly the indicators: reptile species diversity, plant species diversity, and if possible also a measure of invertebrate diversity or abundance (depends on finding additional funds).

Project Objective

This project will improve the scientific basis for the management of kangaroo populations in ACT nature reserves. A measurable relationship will be determined between kangaroo population densities and the conservation impacts of kangaroo grazing pressure.

Outcomes

- More effective, efficient and more defensible management of kangaroo grazing impacts
- Improvement to the existing ecological model which is used as a tool to assist in making kangaroo management decisions
- Reporting of quantitative relationships used in the above model, including the linkage between kangaroo population density and conservation impacts, and the relationship of kangaroo population growth rates to availability and quality of grass and other factors.
- More defensible kangaroo licencing decisions by the Conservator of Flora and Fauna (e.g. see *Department of Defence v's Animal Liberation,* Administrative and Civil Tribunal, 2009)

Outputs

- An updated version of the Kangaroo interactive model
- Reports including survey methods, and results into the relations between
  - kangaroo density and herbage mass
  - herbage mass and reptile occurrence
  - herbage mass and plant species richness
- Statement on the management implication

Budget

Activity	$ 2012/13	$ In kind funding	$ 2013/14	$ In kind funding
Kangaroo density estimation 16 sites, annual ** (Crew leader and 6 labourers for 6 weeks)	0.029	0.010	0.030	0.010
Herbage mass 16 sites, contractor	0.020	0.010	0.021	0.010
Kangaroo offtake (biannual) + small animal species richness e.g. beetles, reptiles (annual), 10 sites, contractor	0.031	0.010	0.031	0.010
Floristics and pasture structure, annual, contractor	0.040		0.041	
Vehicle use, petrol		0.017		0.017
Other consumables – Research equipment		0.005		
TOTAL	**0.120**		**0.123**	

** Existing funding ($32,000 per year) will continue to be used for kangaroo density estimation, bringing this item to a total of $61,200 in 2012-13.

Funding is provided via ACT Government Funding – Recurrent Initiative budget.

Further funding will be applied for to complete the project for a total of six years (See research design in Attachment 1)

Summary of Scope of Work

There are 19 lowland grassland and woodland sites identified for various components of this research project. These sites build on former research and survey that have been undertaken, and provide a range of sites from low and high grazing pressure in which to test the model. At selected sites, eight biodiversity monitoring plots, and four floristic survey plots, will be marked out per site using labelled steel fence posts. Mobile grazing exclusion cages made from steel fence mesh will be added to the plots on seven sites.

At the marked sites, four sets of indicators will be measured:

1. Eastern grey kangaroo density: (14 sites) using one of three methods
2. Herbage mass and kangaroo offtake: (14 sites herbage mass, 7 sites kangaroo offtake)
3. Small animal species richness: (14 sites measured for reptiles)
4. Floristics and pasture structure (17 sites).

The layout of a survey plot is shown in Figure 1. Maps of each site showing plot locations and vegetation strata are in Attachment 2, which is a separate pdf file called '2013 Research Monitoring Plots.pdf' (2.7 Mb) to enable the maps to be emailed with this document. The sites and the measurements proposed to be made at each site are listed in Table 1.

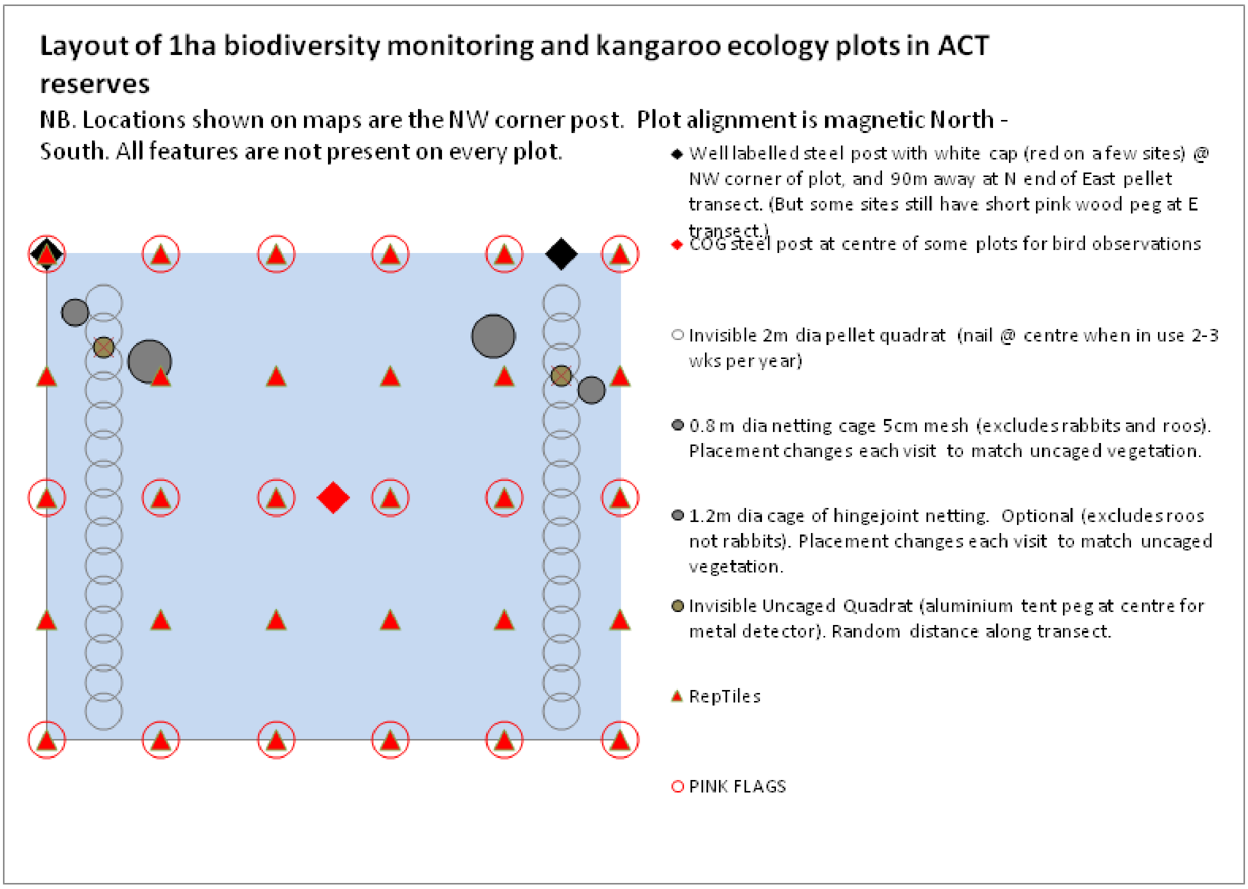

Figure 1: Layout of kangaroo and biodiversity plots

Table 1 - Sites selected and measurements undertaken within allocated budget

SITE (ochre= reptile site, green outline= no roos)	Indicative EGK density at start	Livestock	Cull sites?	Measure EGK Density (EGK/ha)?	Primary count method	Use Kangaroo offtake cages?	Rabbit cages?	Winter herbage mass?	Floristics and vegetation structure (Greg)?	Spring Reptile species richness and Herbage mass
BNTS	**2.5**	N		Y	sweep	Y	Y	Y	Y	Y
Callum Brae	1.0	N	Y	Y	pellet	Y	Y	Y	Y	Y
Crace	0.7		Y	Y	direct	N	N	Y	Y	Y
Farrer Ridge	2.5	N		Y	sweep/pellet	N	N	Y	N	Y
Googong	3.2	N		Y	pellet	Y	Y	Y	Y	Y
Goorooyarroo	1.2	N	Y	Y	pellet	Y	Y	Y	Y	Y
Dunnarts Flat in Gooroo	0.7	N	Y	Y	sweep	N	N	Y	N	Y
Jerra East outside excl	2.5	N		Y	pellet	N	N	Y	Y	Y
Kama	0.6	N	Y	Y	pellet	N	N	Y	Y	Y
Mulanggari	1.2	Y		Y	direct	Y	Y	Y	Y	Y
Mulligans Flat	2.0	N	Y	Y	pellet	Y	Y	Y	Y	Y
Mulligans Flat Dam Padd		N		Y	direct	N	N	Y	N	Y
North Mitchell	0.0	N		no roos		Y	Y	Y	Y	Y
St Marks	0.0	N		no roos		N	N	N	Y	N
Yarramundi	0.0	N		no roos		N	N	N	Y	N
Dunlop	**1**	part		N	direct	N	N	N	Y	N
Jerra West	0.1	N	Y	N		N	N	N	Y	N
NTA	2.0	?		N	direct	N	N	N	Y	N
Wanniassa	1.24	N	Y	N	LT	N	N	N	Y	N
TOTAL no. Sites				12	7 P + 6 visual	7	7	13	16	13
Additional sites that may be counted by others (eg parkcare groups)										
Aranda		N		Y	sweep					
Mt Taylor		N		Y	sweep					
Red Hill	2.16	N		Y	sweep					
Majura Training Area		N								
Mt Painter	2.33	N	Y?	Y	sweep					
Pinnacle	2.1	N	Y?	Y	sweep					
Sites dropped from final research planning										
Jerra East excl DROP?		N		N	direct					
Jerra West excl DROP		N		N	direct					
Throsby Neck at Mulligans DROP?		N		N	pellet					

Scope Detail

1. Kangaroo Population Monitoring:

Kangaroo density will be estimated on 15 sites using 3 methods in winter.

Direct observation counts are the simplest and cheapest method of estimating absolute abundance. This method will be used on small sites with open vegetation where one to three people can see all the kangaroos. At least three independent counts over a few days will be conducted and the average of these will be taken.

Sweep counts will be used in sites that are too large or wooded for the direct observation count method to be used. This method involves a group of people walking in an organised line across the area and counting the kangaroos as they pass between the people. Two or three independent counts will be conducted and the average of these will be taken.

Faecal pellet counts will be used at sites that are too large and wooded for either direct counts or sweep counts to be conducted successfully. This method involves comparing pellet density on the unknown site with pellet density on a site where the kangaroo density is known (a reference site). The plots must be cleared of all kangaroo pellets several weeks before counting.

2. Herbage Mass and Kangaroo offtake:

Herbage mass will be measured on 14 sites and kangaroo offtake will be measured on 7 sites. Herbage mass will be estimated in 1 sqm plots surrounding the reptile monitoring tiles (see below) by comparing with reference photos of cut and dried plots. Kangaroo offtake will be measured by comparing the herbage mass inside caged plots with herbage mass outside caged plots. Cages that exclude all large grazing animals plus cages that exclude kangaroos but not rabbits will be used, to separate the offtake by kangaroos and rabbits. Herbage mass measurements will be collected biannually in Spring (to coincide with reptile surveys) and June. Kangaroo offtake will be measured in January and June.

3. Small animal species richness:

Reptile species richness will be measured on 14 sites. 30 roof tiles will be laid within the 1ha plots (6 rows of 5) to act as artificial shelters for reptiles. Each tile will be checked for the presence of reptiles at least 8 times in spring. The optimum temperature range for checking tiles is 8-20 degrees. Reptiles will be identified to species level and released. During the survey period, the herbage mass of the vegetation surrounding each tile that caught a reptile and a subset of the tiles that did not catch a reptile will be estimated.

4. Vegetation Parameters:

There are four methods used to collect vegetation data for measuring grazing impacts.

1. Species richness within pre-determined 20x20m quadrats. The data derived from this method allows for assessments of native and exotic species richness as well as a quantitative Floristic Value Score (FVS). This score allows comparisons to be made between quadrats from different sites.
2. Step Point assessments are completed over a pre-defined 100m transect. This data is used to calculate the percentages of bare ground, litter, perennial native and perennial exotic species.
3. Indicator Forb Abundance involves counting the individuals of a number of pre determined forb species in a 20 square metre area around the perimeter of the quadrat. This measure allows abundance data to be used in conjunction with species richness data and the two measures provide a possible way of determining optimum kangaroo densities.
4. 2D line-transect structure measurements (LSM) used to quantify sward height and variability.

Data entry

Data entry will be completed by CPR staff and entered into excel spreadsheets.

Data Anaylsis

When sufficient annual rates of population growth and pasture growth have been measured (from sufficient sites x years) a new numerical response equation will be calculated and placed into the ACT Kangaroo Interactive Model. There is the potential for this to alter the management advice for culling on both rural and conservation areas. The management implications will be reported.

Floristic and pasture structure analysis will focus on identifying significant differences between vegetation parameters with different kangaroo densities or on trends within those parameters between sites and years. The aim of this analysis will be to inform decisions about optimum kangaroo densities for each parameter.

Reptile response to herbage mass will require sophisticated analysis, possibly a combination of PCA and information theoretic methods. It is likely that each reptile species will have a different optimum grazing regime. This will need to be reported as a prelude to managers making decions jointly with research ers about which species to optimise for, eg striped legless lizard in Mulanggari and three-toed skink in Gungaderra.

The research design is outlined in Attachment A, noting that some operational constraints may limit the survey of all attributes at all sites each year. The research design includes the assumptions and strategies that underlie the survey and monitoring methods and includes a full description of the methods to be used.

Reporting

1. Annual reports to be produced for both 2012/13 and 2013/14 including information on each indicator, recording work completed, any obvious and interesting results and any problems or necessary changes in direction reported.
    a. Kangaroo Density Estimation, Herbage Mass, Kangaroo Offtake and Reptile species counts
    b. Vegetation Parameters in relation to kangaroo density
2. A final report incorporating all the data (including any previous data of relevance) is to be delivered by August 2014, after completion of this stage of the project in June 2014.
3. A full Conservation Research Technical Report incorporating other fauna data and vegetation data is to be delivered by January 2015.

Should the full research project be funded for the full 6 years, after six years – full analysis with AIC-based selection (for Aikaike's Information Criterion – the core of Information Theoretic statistical methods) of the best statistical models for the principal relationships of interest, especially the 'herbivore numerical response'. An update of the ACT kangaroo interactive model and a full review of the results and information from the program. (Funding permitting)

Approvals required

Animal Ethics Committee approval is required to conduct some components of this project. These components are covered by two project approvals from the University of Canberra Animal Experimentation Ethics Committee: CEAE 13_01 - Estimating abundance of macropods and CEAE 12-08: Measuring the impact of eastern grey kangaroo density on vegetation mass and reptile diversity. The necessary reporting and renewal requirements for these projects will be organised and undertaken through Conservation Research ESDD (Don Fletcher).

Site access approvals are required for Majura Training area and Belconnen Naval Transmission Station (and unexploded munitions training).

Evaluation

Scientific evaluation of the project will be provided in a final technical report. An external review of this report is likely to be undertaken. External assistance may be required for some statistical analysis.

Project Managers

Greg Baines, Senior Vegetation Ecologist

Don Fletcher, Senior Fauna Ecologist

Margaret Kitchin, Manager Conservation Research Unit, oversight of the program.

Attachment: Risk Register

Risk Register															
Risk without any controls									Risk with current controls						Risk Trend
Risk Ref #	Priority	Risk	Source	Expected Consequences/Impact	Likelihood	Consequence	Rating	Risk Rating	Existing Controls	Control Assessment	Likelihood	Consequence	Rating	Risk Rating	
1		Treasurey Budget is not forthcoming for 2014/16 financial years (2 years)	Government Funding restricted	• Project would not be completed • Kangaroo Model not updated sufficiently to provide scientific advice	**Possible**	**Major**	**High**	**HI**							
2		KMP Implementation Recurrent Funding not forthcoming	Government Funding restricted	• Project would not be completed • Kangaroo Model not updated sufficiently to provide scientific advice											
3		Malicious damage to plots	Vandalism	• Project delay or project failure	**Unlikey**	**Major**	**High**								
4		Current budget is not sufficient	Changes in scope or unexpected incidents in field work	• Project would be scaled back (reduce number of sites assessed)	**Unlikely**	**Minor**	**Low**								

Risk Register

Risk without any controls									Risk with current controls						Risk Trend
Risk Ref #	Priority	Risk	Source	Expected Consequences/Impact	Likelihood	Consequence	Rating	Risk Rating	Existing Controls	Control Assessment	Likelihood	Consequence	Rating	Risk Rating	
5		Weather conditions, unpredictable natural disaster	Variable	• Poor weather can delay pellet counting and/or require the pellet counting component to be repeated • Natural disaster, e.g. fire or flood • may delay project	**Possible/unlikely**	**Major**	**High**								
6		Change in management of site	TAMS or NCA manage land differently – eg. Introduce grazing, or conduct hazard reduction burn	• possible that monitoring sites could be severely effected					Good communication maintained with TAMS and NCA						
7		CPR Restructure	Change in priorities under new management	•											
8		Loss of Data	Computer malfunction, field sheets misplaced	•					Computer backup						

Attachment 1

RESEARCH DESIGN: KANGAROOS AND CONSERVATION: RELATIONSHIPS BETWEEN KANGAROO DENSITY, HERBAGE MASS, PASTURE FLORISTICS AND REPTILE DIVERSITY IN GRASSY ECOSYSTEMS AROUND CANBERRA

Revised May 2013

AIMS

1. To provide management advice based on quantitative empirical assessments to guide the management of grazing pressure, particularly from kangaroos, in lowland grassland and grassy woodland areas of conservation value. The advice by Morellet *et al*. (2007) for monitoring vegetation-herbivore systems is favoured, namely that the measurements should including abundance of large herbivores, indicators of herbivore performance, indicators of grazing pressure, and indicators of grazing impact such as change in biodiversity;

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3. To monitor the condition of representative lowland native grassland and woodland sites in the ACT in relation to kangaroo grazing pressure, particularly the indicators: reptile species diversity, plant species diversity, and if possible also a measure of invertebrate diversity or abundance (depends on finding additional funds).

GLOSSARY

Biomass is the dried weight of living material expressed as a density, e.g. kilograms per hectare, with its components, such as plants, fungi, or animals, often stated separately. In reference to vegetation, the term has often been used as a synonym for 'herbage mass', but the more precise term 'herbage mass' is preferable. One of the threatened species of the grasslands, the golden sun-moth, is likely to be influenced more by the root biomass, than by the herbage mass, so the more correct terminology may have practical advangates in refining the thinking about relevant ecological processes, and research designs. Thus, **pasture biomass** here refers to the total dried weight of the living pasture vegetation, i.e. including roots, but not including the dead component, or **necromass**, such as thatch, with 'herbage mass' used here to refer to the above ground component of plant biomass.

Ecology is the scientific study of the relationships that determine the abundance of living organisms (Krebs 2001).

Herbage mass is synonymous with the agronomic term '**yield'** and refers to the grazable (or clippable) component of the pasture above ground level, including both dead and living plant parts. It is commonly subdivided into dead (necromass) and living (biomass) components, and the Dry Weight Rank method (t'Mannetje and Haydock 1963) is routinely used to subdivide it by species. **Green herbage mass** is the living portion of clippable above ground pasture, which is what herbivores seek. In temperate grazing studies it is usually necessary to use green herbage mass in preference to (total) herbage mass to discern or model the relations between weather, pasture and herbivores. Eastern grey kangaroos eat mainly green grass and few forbs, so **Green grass herbage mass** is the preferred variable in this case.

Monitoring is a type of applied ecology research involving evaluation of data collected over several years or longer, possibly decades.

Pasture is non-woody ground layer vegetation subject, or potentially subject, to grazing by large animals.

Species Richness is a statistical index of the number of species within a taxonomic group that are present, e.g. the number of plant species in a reserve. A so-called 'jackknife' estimate is used to account for the probability of missing some species in any count, where $SR = ((n + n-1) / n)^k$ where SR = Species Richness; n = number of species counted; and k = number of species of which only one organism was found.

Species Diversity index is a mathematical measure of species diversity which provides more information about community composition than species richness because it also takes account of the relative abundances of different species. Thus it reflects the evenness with which individuals are distributed among the different species, as well as the total number of species. Species diversity indexes include Simpson's D, Shannons H, the Berger-Parker index (*d*), Hill's N_1, and Q-statistics. Each of these indexes has strengths and weaknesses. An ideal index would discriminate clearly and accurately between samples, not be greatly affected by differences in sample size, and be relatively simple to calculate. Biologists often use a combination of several indexes to take advantages of the strengths of each and develop a more complete understanding of community structure. See Krebs (1999) for helpful suggestions and worked examples. Abundance must be estimated for each species, in order to calculate any of the species diversity indexes. This is an important consideration for the monitoring design.

Units

Herbage mass, biomass, and necromass are always expressed as **densities**, in the form of dried mass per unit area, and in agronomic or ecological studies the units are generally kilograms (dried weight) per hectare, as intended here. However in most studies the animal density is represented as numbers, rather than mass, per unit area, with the exception of the GMM (Growth Metabolism Mortality) school of thought (Owen-Smith 2002a, b), a so-called 'metaphysiological' approach which represents both the plant and animal populations as mass per unit area. One square kilometre (sq km or km^2) is 100 hectares (ha) so a density of 1 kangaroo / ha equals 100 kangaroos / sq km.

ASSUMPTIONS AND STRATEGIES UNDERLYING THE MONITORING DESIGN

Strategic assumptions/ research design

1. Biodiversity change is a consequence of ecological change. Ecological changes may be:
    - in the flows of energy and materials
    - a shift to an alternate stable state (e.g. overgrazed/undergrazed, predator pit); or
    - altered prey selection pressure eg by replacing kangaroos with cattle.

    This program aims to measure ecosystem processes, not just biodiversity losses and gains.

2. Weather has a major influence on grassy ecosystems. Although the ACT region is a temperate environment, and relatively stable compared to much of Australia, there is still a 27% CV of rainfall between years, and large differences in pasture growth. To discern the effect of a management treatment, temporal comparison (comparing conditions before and after a change of management) is usually unreliable. Spatial comparison between areas with different treatments (sites or plots) is highly desirable.

3. Because of site or sampling differences, it may be more useful to compare the rates of change in a variable between sites, than the absolute values of the variable (Morellet *et al*. 2007).

4. The effect of a management treatment may be more reliably assessed over several years, rather than one or two.

5. Natural Temperate Grassland is an endangered ecological community and the management aim in grasslands reserved for conservation is to prevent impacts as much as possible (rather than recording them, and then responding to them) Therefore, if the kangaroo management plan is to be successful, its implementation can not be based on monitoring impacts, or waiting for thresholds to be crossed. This needs to be considered in the research design too. It would be irresponsible to obtain good research results by comparing unmanaged and culled areas of an endangered ecosystem. if

6. Point 5 limits the application of point 2 to non-endangered communities. To obtain experimental rigor, we have to use some sites where the endangered community is absent or not well developed!

7. Also from point 5, the ‘management prescriptions’ used to decide what action to take in a reserve should not be based only on the monitoring results, but primarily on principles derived from research on the interactive relationships between grazed pastures and grazing animals, and on significant plant and animal species of the grasslands;

8. Recent ACT research, leading to an ecological model of kangaroo-pasture dynamics in local weather conditions, will be a significant source of information used to develop and analyse grassland /woodland management prescriptions;

9. The condition of a declining pasture-herbivore system is likely to be detectable first, and seen best, in the condition of the pasture, rather than the condition of the herbivores, but conversely, the abundance of the herbivores is the variable most readily used to govern the system;

Ecological assumptions

10. The ecological effect of large grazing animals such as kangaroos (e.g. disturbance) is essential for grassland biodiversity conservation, so periodic grazing, or some other disturbance which removes herbage mass, such as burning or mowing, is essential;

11. However, continuous removal of herbage to a low level, for periods of years, and consequent simplification of the habitat structure, is likely to reduce animal and plant biodiversity, whether removal is by herbivores, by frequent close mowing, annual burning, or other means;

12. Control of herbage mass (e.g. by controlling grazing) is an important mechanism of preserving grassland biodiversity, i.e. it is an important means of managing the abundance of uncommon plant and animal species;

Ecosystem processes which this monitoring will estimate

13. It is sensible to start by considering the main ecosystem processes which may be related to the goals of monitoring. The following figure (Figure 1) illustrates these in highly simplified form.

IMPORTANT ECOLOGICAL PROCESSES IN CONSERVATION GRASSLANDS, OUTLINED AS AN INTERACTIVE MODEL, AND CONSEQUENT RESEARCH PRIORITIES

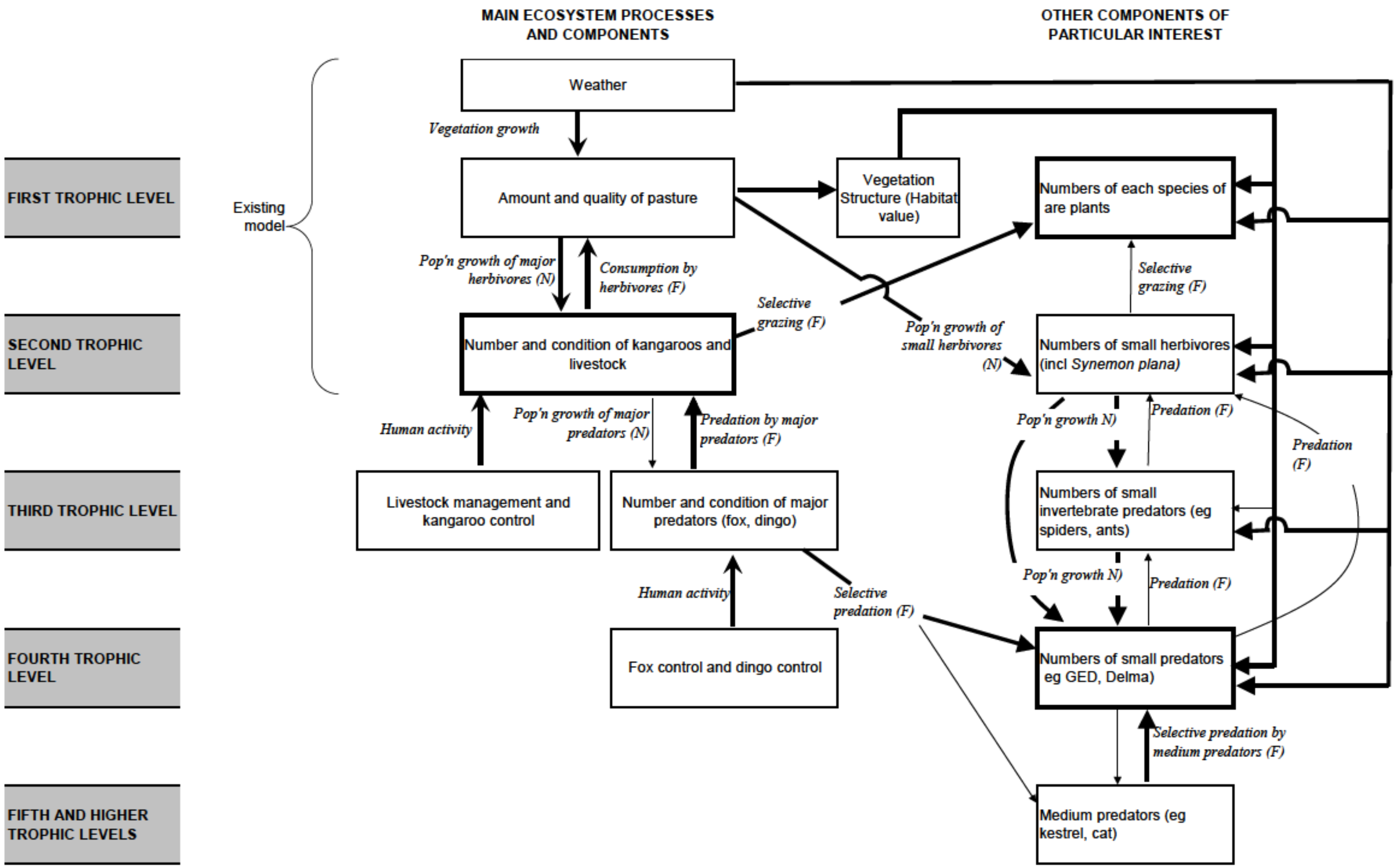


Figure 1: A topical question is the effect of grazing by kangaroos and livestock on threatened grassland animals and plants. However there is no direct relationship between these (no arrows directly linking the boxes for kangaroos and GED, for example). To evaluate the relationship, ultimately it is desirable to estimate the relationships along the indirect pathway that links the two, as well as the magnitude of alternative factors such as direct effects of weather on the threatened plants and animals. N= Numerical Response, F= Functional Response, Pop'n= Population, GED=Grassland Earless dragon, Delma= Striped Legless Lizard. Bold boxes enclose components of special public interest or legal status. Bold arrows indicate processes considered of greater importance to monitor. Barbed arrows mark processes for which estimation has commenced. The main ecosystem processes (left column of boxes) have been estimated once, and represented in an interactive model. The state of the major components on the left is likely to influence those on the right, but not the reverse.

METHODS

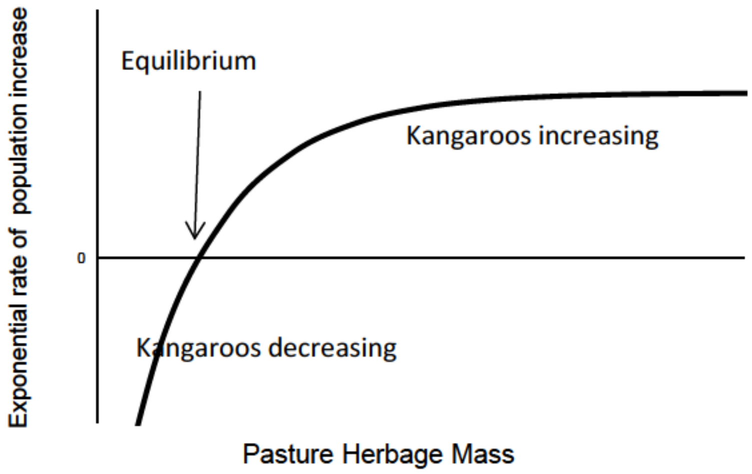
To manage a vegetation-herbivore system, Morellet *et al*. (2007) recommend the monitoring of four sets of indicators, herbivore abundance, herbivore performance, environmental condition, and environmental impact indicators. This advice, based on many years of experience, especially with roe deer in France, has been adopted, as follows. However the kangaroo condition component has been dropped for budget reasons (struck-through text).

Monitoring methods summary

What is monitored	Technique	When
Herbivore Abundance	Kangaroo density will be measured by either direct counts, sweep counts, pellet counts or line transect counts (See Appendix 1 of KMP for explanation of methods)	Mid May – Mid June
~~Herbivore Performance~~	~~Shot sample to assess veterinary health of kangaroos and measures of fecundity, age structure, fat levels, and age-specific weights of py and sub-adults.~~	~~Early July~~
Environmental condition indicators and Impact indicators	Herbage mass	May-June, Nov-Dec.
	Pasture-consumption rate, as caged minus uncaged herbage mass, per day	May-June, Nov-Dec.
	Tussock structure index such as Ratio Foliar cover/ basal cover	Spring
	% cover of: bare, litter, dead, live exotic grass, live native grass, live exotic forb, live native forb in NTG.	Spring
	Abundance of presumed grazing-sensitive indicator species.	Spring
	Plant species diversity	Spring
	Reptile diversity	Spring - Summer

Minimum data collection requirements

A minimum number of sites (reserves) and years is required, as follows. Many of the ecological relationships to be evaluated are inherently non-linear, and based on annual rates, such as population growth rate. For example, a numerical response curve is illustrated below for kangaroos and pasture herbage mass. To fit non-linear relationships (by MLE or least squares) 25 data points is a reasonably minimum standard to consider at the design stage. Each annual rate measurement results from two consecutive annual measurements. For example a measure of kangaroo population growth rate is obtained by dividing the count in year one into the count in year two. Thus for example, five sites measured annually for six years produce 25 points for the regression. Experience warns us to expect a high rate of attrition of sites (eg the dropping of Jerrabomberra West) so we need to start with at least 15 sites. If 11 of these produce annual data without major disruption from unexpected livestock grazing, hazard reduction burning, bushfires or other disruptions, the number of points will be 11 after year two, then 22, 33, 44 and after six years 55, which will hopefully be a good number for determining the underlying ecology.



Stratification

Allocation of sampling points will be stratified by vegetation structure (Grassland, Open Woodland, Woodland etc) and possibly also by grassland association: Themeda, Stipa, etc. A high priority is to objectively map vegetation structure at an early stage.

Herbage mass and offtake

Herbage mass will be measured by the Comparative Yield method (t'Mannetje and Jones 2000) and partitioned into species by the Dry Weight Rank Method (t'Mannetje and Haydock (1963). Offtake (kg/ha/day) will be measured as the difference between sets of three herbage mass measurements in matched plots, one of which is uncaged, one caged to exclude kangaroos only (large mesh) and the third caged to exclude both kangaroos and rabbits. The mean of the measured differences is divided by the number of days since caging to give offtake in kg/ha/day for each herbivore population.

Indicator plant species

Grazing-sensitive plant species tend to be tall forbs with constrained morphology (not plastic), which are succulent rather than fibrous, and not protected by spines. In addition, the list of indicator species should seek those plants whose abundance on a site is declining toward extirpation, or recovering. (One of our questions is whether that change is due to changed grazing pressure, or something else.) EGKs eat little of dicotyledenous plants and are not known to eat any of the species on the list. Impact on those would arise indirectly e.g. through changes in habitat structure. Species have been chosen because they are less common (probably because of past site disturbance) and likely to be impacted by grazing. There are a range of very uncommon to uncommon species (ie found in less than 50% of sites). Note that timing is really important to detect many of these species – mid Oct to mid November at the latest.

Table 1 Indicator Species

Ajuga australis	Austral Bugle (woodland)	*Microseris lanceolata*	Yam Daisy
Arthropodium milleflorum	Vanilla lily	*Microtis parvifolia/unifolia*	Slender Onion Orchid
Austrostipa densofolia	Brushtail Speargrass	*Microtis* sp.	
Brachyscome heterodonta	Lobe-seed Daisy	*Pimelea curviflora*	Curved Rice Flower
Bulbine bulbosa	Bulbine lily	*Ranunculus/Geranium* spp	
Burchardia umbellata	Milkmaids	*Geranium solanderi*	
Calocephalus citreus	Lemon Beautyheads	*Scleranthus biflorus*	
Craspedia variabilis	Billy Buttons	*Sorghum leiocladum*	Wild Sorghum
Dichelachne spp	Plume grasses	*Stackhousia monogyna*	Creamy Candles
Dichopogon fimbriatus	Chocolate lily	*Stylidium graminifolium*	Grass Triggerplant (woodland)
Eryngium ovinum	Blue Devil	*Swainsona* spp	Swainson peas
Eryngium rostratum	Blue Devil	*Thysanotus tuberosus*	Common Fringe-lily
Goodenia pinnatifida	Scrambled Eggs	*Wurmbea dioica*	Early Nancy
Leucochrysum albicans	Hoary Sunray		

Sites within sites

Kangaroo density, ~~kangaroo condition~~, herbage mass and herbivore offtake will be measured across a wider 'site' i.e. the reserve or KMU, than species diversity. The former needs to encompass all the main feeding areas of the livestock and kangaroos, whether the pasture used by the herbivores is exotic or native. However the floristic measures, such as species diversity index, will be restricted to areas classified as natural temperate grassland (NTG and the reptile diversity index will be restricted to areas of grassland and open woodland).

Threshold effects

All ACT lowland reserves are substantially degraded and missing keystone species. Because of threshold effects it is unrealistic to expect early response from all variables to ecological restoration measures such as reducing kangaroo herbivory, or hypothetically, adding a kangaroo predator (Hobbs and Norton 1996). More likely some aspects of recovery will be delayed and the delay is likely to vary between reserves, depending on their management history.

Analysis

A variety of statistical approaches is needed. For the reasons given in the preceding section, some moderately sophisticated approaches are necessary such as mixed effects models, or information theoretic approaches. As indicated under '*Minimum data collection requirements'* maximum likelihood estimation (preferably) or least squares non-linear regression will also be needed in a number of cases.

SITES SELECTED and measurements budgeted for

SITE (ochre= reptile site, green outline= no roos)	Indicative EGK density at start	Livestock	Cull sites?	Measure EGK Density (EGK/ha)?	Primary count method	Use Kangaroo offtake cages?	Rabbit cages?	Winter herbage mass?	Floristics and vegetation structure (Greg)?	Spring Reptile species richness and Herbage mass
BNTS	**2.5**	N		Y	sweep	Y	Y	Y	Y	Y
Callum Brae	1.0	N	Y	Y	pellet	Y	Y	Y	Y	Y
Crace	0.7		Y	Y	direct	N	N	Y	Y	Y
Farrer Ridge	2.5	N		Y	sweep/pellet	N	N	Y	N	Y
Googong	3.2	N		Y	pellet	Y	Y	Y	Y	Y
Goorooyarroo	1.2	N	Y	Y	pellet	Y	Y	Y	Y	Y
Dunnarts Flat in Gooroo	0.7	N	Y	Y	sweep	N	N	Y	N	Y
Jerra East outside excl	2.5	N		Y	pellet	N	N	Y	Y	Y
Kama	0.6	N	Y	Y	pellet	N	N	Y	Y	Y
Mulanggari	1.2	Y		Y	direct	Y	Y	Y	Y	Y
Mulligans Flat	2.0	N	Y	Y	pellet	Y	Y	Y	Y	Y
Mulligans Flat Dam Padd		N		Y	direct	N	N	Y	N	Y
North Mitchell	0.0	N		no roos		Y	Y	Y	Y	Y
St Marks	0.0	N		no roos		N	N	N	Y	N
Yarramundi	0.0	N		no roos		N	N	N	Y	N
Dunlop	**1**	part		N	direct	N	N	N	Y	N
Jerra West	0.1	N	Y	N		N	N	N	Y	N
NTA	2.0	?		N	direct	N	N	N	Y	N
Wanniassa	1.24	N	Y	N	LT	N	N	N	Y	N
TOTAL no. Sites				**12**	**7 P + 6 visual**	**7**	**7**	**13**	**16**	**13**
Additional sites that may be counted by others (eg parkcare groups)										
Aranda		N		Y	sweep					
Mt Taylor		N		Y	sweep					
Red Hill	2.16	N		Y	sweep					
Majura Training Area		N								
Mt Painter	2.33	N	Y?	Y	sweep					
Pinnacle	2.1	N	Y?	Y	sweep					
Sites dropped from final research planning										
Jerra East excl DROP?		N		N	direct					
Jerra West excl DROP		N		N	direct					
Throsby Neck at Mulligans DROP?		N		N	pellet					

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ADDENDUM

Previous monitoring

According to the ACT Grasslands Strategy, all of the larger and most important ACT lowland native grasslands have been thoroughly surveyed, mostly several times (ACT Government 2005, p 50). In addition, permanent transects in up to fourteen ACT lowland natural temperate grasslands were monitored annually in spring from 1993 to 2002 (ACT Government 2005, p 50). File records show that each of the sites was nominated as either grazed by livestock, burnt, mown, or untreated. It was expected that the data would be used for many purposes but the main goal was to 'devise and refine the management regimes' for grasslands generally, and the Grasslands Strategy (ACT Government 2005) states the goal was also to 'identify slow, largely imperceptible changes in the flora of the ecological community'.

The data from this period illustrate considerable variation, thought likely to be due to between-year variation in weather, and also due to changes in the management of many of the sites. The high variability has so far prevented the detection of trends or effects. That is, not only the 'slow largely imperceptible' changes, but also the effects of management (grazing / burning / mowing / no treatment), are imperceptible amid the background variation. In other words, the statistical power of the monitoring design was too low to achieve its goals, where 'design' includes all influences such as variable weather, management effects, sites differences, sample size, change between years in the quadrats visited, and changes in the sampling process.

Proposed monitoring (This was written in 2008 and has had to be cut back)

Having completed the ten years of field monitoring (1993 to 2002), followed by five years without a formal grassland monitoring project, it was decided in 2008/09 to seek funds to re-commence the monitoring of grasslands, with a modified research design. As well as the need to address the design issues mentioned above, some important changes have happened in the interim. First, the potentially critical role of natural herbivory in grassland ecology has received official recognition. [Natural grazing is not recognised as a potentially important threat in either the Grasslands Strategy (ACT Government 2005), or in the 1993 to 2002 monitoring design.] The appointment of the Commissioner for Sustainability and Environment to inquire into the grazing by kangaroos at the Belconnen Naval Transmitting Station (BNTS), and subsequently into the management and condition of ACT grasslands generally, was a pivotal point in the management history of ACT grasslands, as was the Chief Minister's direction to the TAMS Department to prepare an ACT Kangaroo Management Plan, arising from his concern that the degradation of natural temperate grasslands on the Defence sites in the ACT due to kangaroo grazing, was also underway in ACT reserves.

So, what will be changed in the new grasslands monitoring project, compared to the monitoring program of 1993-2002? First, the new program will be closely integrated with other grasslands monitoring projects, particularly any monitoring of grassland earless dragons (GED), eastern grey kangaroos (EGK), striped legless lizards, golden sun-moths, and threatened grassland plant species. In particular, this monitoring will be integrated with projects underway to quantify home range and movements of urban EGKs. Second, the grassland monitoring will concentrate on grazing effects (especially kangaroos but including livestock), with the monitoring of the effects of burning, and mowing to be included only if additional resources become available. Third, a power analysis will be conducted on pilot data to evaluate the potential to obtain useful information from the work. Based on that analysis, if necessary, larger sample sizes and stronger management effects will be used to increase the likliehood of a successful project. Stronger effects may involve, for example, kangaroo culling, or treatments at the scale of 'plots' rather than sites, an example of a 'plot' being a paddock where kangaroos and livestock are kept at lower density than in the surrounding area. Compared to 1993-2002, essentially it is a case of having to measure fewer things better, and of more fieldwork hours having to be put into the program.

This need not cause concern about valuable grasslands being neglected. Although the main emphasis will be directed to obtaining sufficient measurements of the most important type in selected grasslands, nevertheless the management condition of all high quality natural temperate grasslands will also be lightly monitored. If possible, additional research will be added in future on effects of burning and mowing, weed control, etc, but grazing is widespread, increasing, and has powerful effects, therefore is the priority. Likewise, the natural temperate grasslands of the lowlands will be the priority, with limited survey and monitoring in the natural temperate grasslands of Namadgi and other areas at higher elevation.

A preliminary estimate of kangaroo density will be conducted in 2008 to help select sites and assign management treatments. If there is not an adequate range of variation likely to be available naturally in grazing pressure, from no grazing to heavy grazing pressure, it may be necessary to impose management treatments (eg kangaroo shooting, or herding kangaroos out of leaky 'exclosures') to obtain the essential contrast in grazing conditions between sites. The level of monitoring effort needs to be limited to what is realistically achievable, yet must also be sufficient to provide unequivocal results on which management decisions can be based (e.g. to shoot / not shoot kangaroos). History of the ecosystem normally contributes to results, as well as conditions at the time the response variables are measured, therefore the effect of time lags should be explored.

Attachment 2: See separate file called ‘2013 Research Monitoring Plots.pdf’ (2.7 Mb)