Springbrook Rescue

Monitoring and Evaluation
of
Ecological Restoration

Extract (1-15 pp.)

Australian Rainforest Conservation Society Inc.

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Contents

Introduction

History

During the period 2004–2009 the Queensland Government purchased 46 properties totalling 708 hectares in the Springbrook area in order to expand the existing National Park and World Heritage Area. The small National Park was included in the Gondwana Rainforests of Australia World Heritage Area in 1994 (then called the Central Eastern Rainforest Reserves of Australia). The area is part of 15 nationally designated 'hotspots' identified in October 2003[1] as "the most threatened and biodiverse centres in Australia". The area is also part of an internationally recognised biodiversity hotspot "Forests of East Australia"[2] first recognised in 2011. Australia is also officially recognised as one of the 17 megadiverse countries in the world with the highest numbers of endemic vertebrate species (excluding fish) and the fifth highest number of endemic vascular plant species in the world[3]. Springbrook, in the McPherson Ranges, is a key part of these centres of endemism.

Properties were acquired on the basis of three primary criteria:

(a) ecological and evolutionary significance contributing to World Heritage values;
(b) feasibility and capacity for regeneration of cleared and/or disturbed areas
(c) recovery of critical habitat and landscape integrity and functional connectivity

ARCS was a member of the Steering Committee with oversight of the acquisition program, and provided advice relating to the above primary criteria. The expert advice, having been responsible for preparation of three of Australia's successful World Heritage nominations, was based on comprehensive on-ground surveys and evaluation reports on World Heritage values and integrity as defined in the Operational Guidelines of the World Heritage Convention. All work conducted by ARCS was carried out *pro bono*. These reports are available on the ARCS Springbrook Rescue website.

In 2008, ARCS entered into a ten-year licence agreement with the Queensland Government, renewable for a further 10 years, to undertake, *pro bono*, the long-term rehabilitation of properties which were transferred to National Park (Recovery) in January 2012. Oversight of the rehabilitation program is through a Steering Committee and a Scientific Advisory Committee the composition and functions of these committees being defined within the Licence Agreement. This Licence Agreement is available on the ARCS Springbrook Rescue web site.[4]

In early 2010, ARCS provided the Department of Environment and Resource Management (DERM) with a progress report, *Springbrook Rescue Restoration Project — Performance Story Report 2008–2009*.[4] This foundation report details the context, program logic, risk assessment, the scientific basis for the restoration project, and the framework for monitoring, evaluation, review and improvement (MERI).

The second Progress Report[4] was provided to the Queensland Government in September 2011 and the third in early 2013[4].

In addition to the above properties purchased by the Queensland Government, a further 208 hectares of land in the Waterfall Creek Catchment was donated to ARCS in 2008–2009 for long-term protection and restoration. Restoration of Ankida is a separate but integral part of the overall Springbrook Rescue Project. The valley contains the low altitude (200 m) extreme of environmental gradients covered in the Project.

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1 http://www.environment.gov.au/biodiversity/hotspots/national-hotspots.html

2 Zachos, F.E and Habel, J.C. (Eds.)(2011) Biodiversity Hotspots: Distribution and Protection of Conservation Priority Areas. Springer, 546 pp.

3 http://www.environment.gov.au/soe/2001/publications/theme-reports/biodiversity/biodiversity01-3.html

4 http://www.springbrookrescue.org.au/ProgressReports.html

Monitoring and Evaluation

The background to this report is fully documented in the foundation report (*Springbrook Rescue Restoration Project — Performance Story Report 2008–2009*) and the second *Progress Report* (September 2011) and this document needs to be read in conjunction with both these reports. To facilitate planning, budgeting, implementation, adaptive management and progress reporting, all aspects of the overall program are framed as fully integrated individual sub-projects.

Monitoring, evaluation and reporting processes cover ecological and social aspects within a social-ecological systems framework (Cairns and Heckman 1996). All restoration involves learning how to most cost-effectively, efficiently and successfully repair anthropogenic damage to the integrity of ecological systems.

Key Assumptions

1. Ecological systems are considered in this project to be complex, self-organising adaptive systems capable of existing in multiple alternative states depending on historical contingencies (e.g. year effects, priority effects, disturbance regimes)
2. Community assembly can be both deterministic and historically contingent — deterministic in the general composition of trait-based functional groups, but historically contingent in the specific composition of species:
    a. stochastic forces producing variation in the sequence and timing of species arrivals can cause divergence in community structure among localities even under identical environmental conditions and regional species pool (Drake 1990; Law and Morton 1993)
    b. deterministic forces (the available species pool, environmental conditions such as resource supply and climate, and natural disturbance regimes) determine the types of available niches and therefore the functional groups that can fill them
3. Assisted natural regeneration is the preferred approach (Shono *et al.* 2007) wherever the natural species pool and dispersal are not significantly limiting. The presumption is that this method is simpler and more cost-effective than conventional planting methods. Interventions are only to accelerate rather than replace natural successional processes by removing or reducing resource and disturbance constraints to natural regeneration.

Conceptual Models

Whether explicit or implicit, all monitoring of the effectiveness of ecological restoration is based on a mental model of how one thinks ecosystems function.

Our ecological and social conceptual models (Figures 1 and 2 respectively) provide a systems approach to measuring ecosystem responses to primary drivers of change. They help identify if, how and when we need to intervene in order to achieve our restoration goals.

Thirty-five projects have been developed to assess the drivers and response variables in the ecological model and monitor achievement of desired outcomes defined in Figure 3.

A detailed discussion of the Biodiversity-Stability Model occurs in the next section.

Conceptual Models underlying Springbrook Rescue Projects

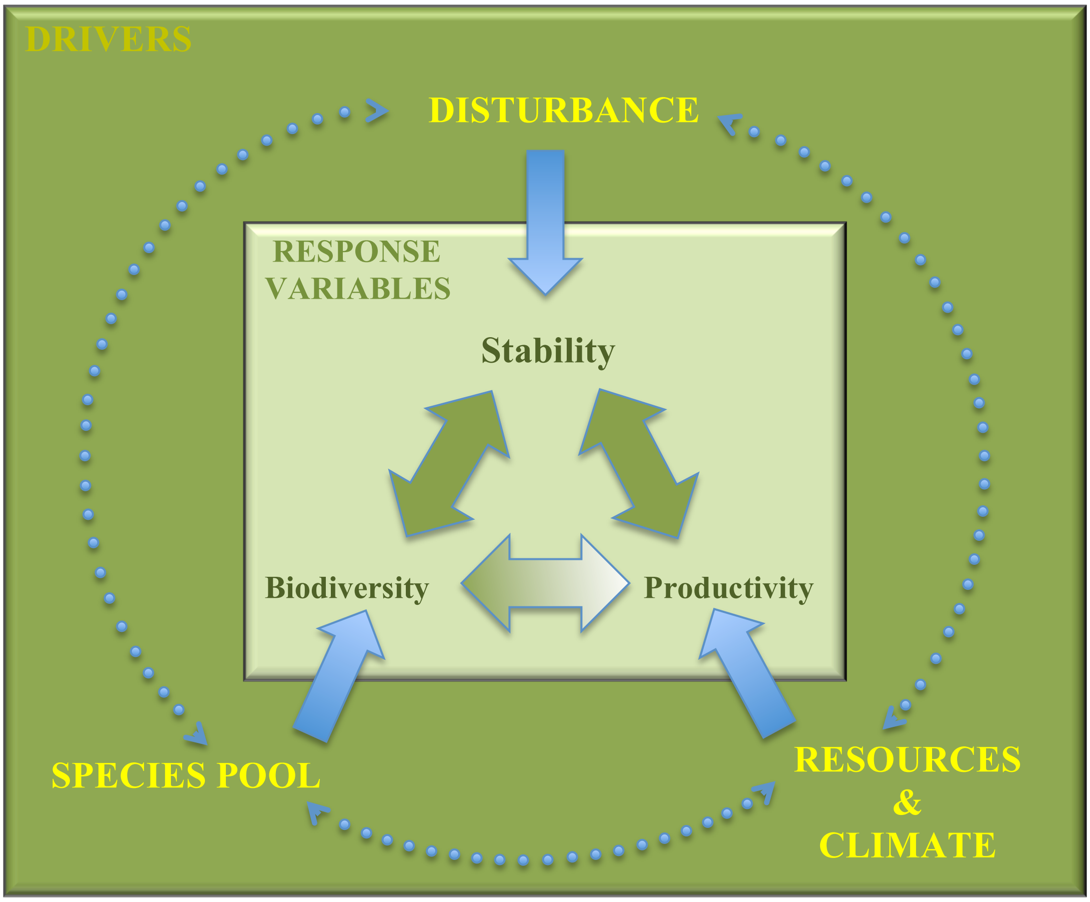


Figure 1. Ecological conceptual model

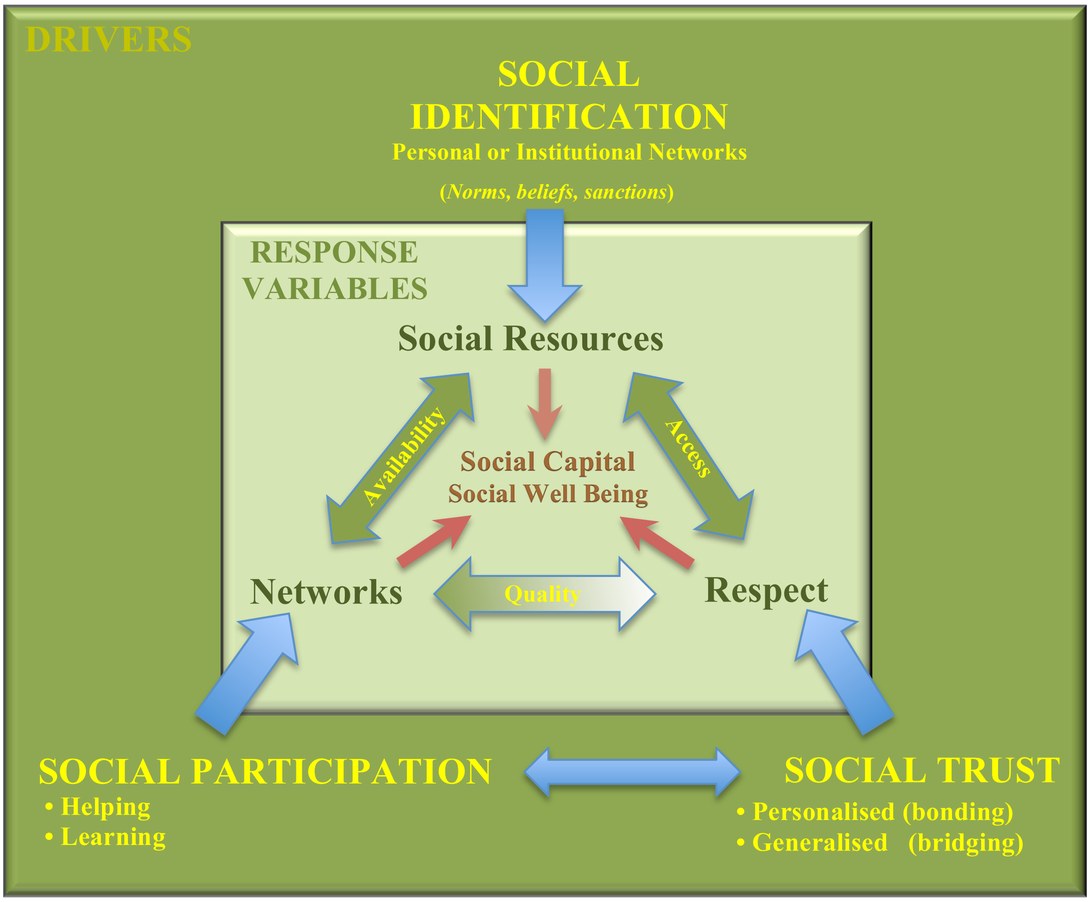
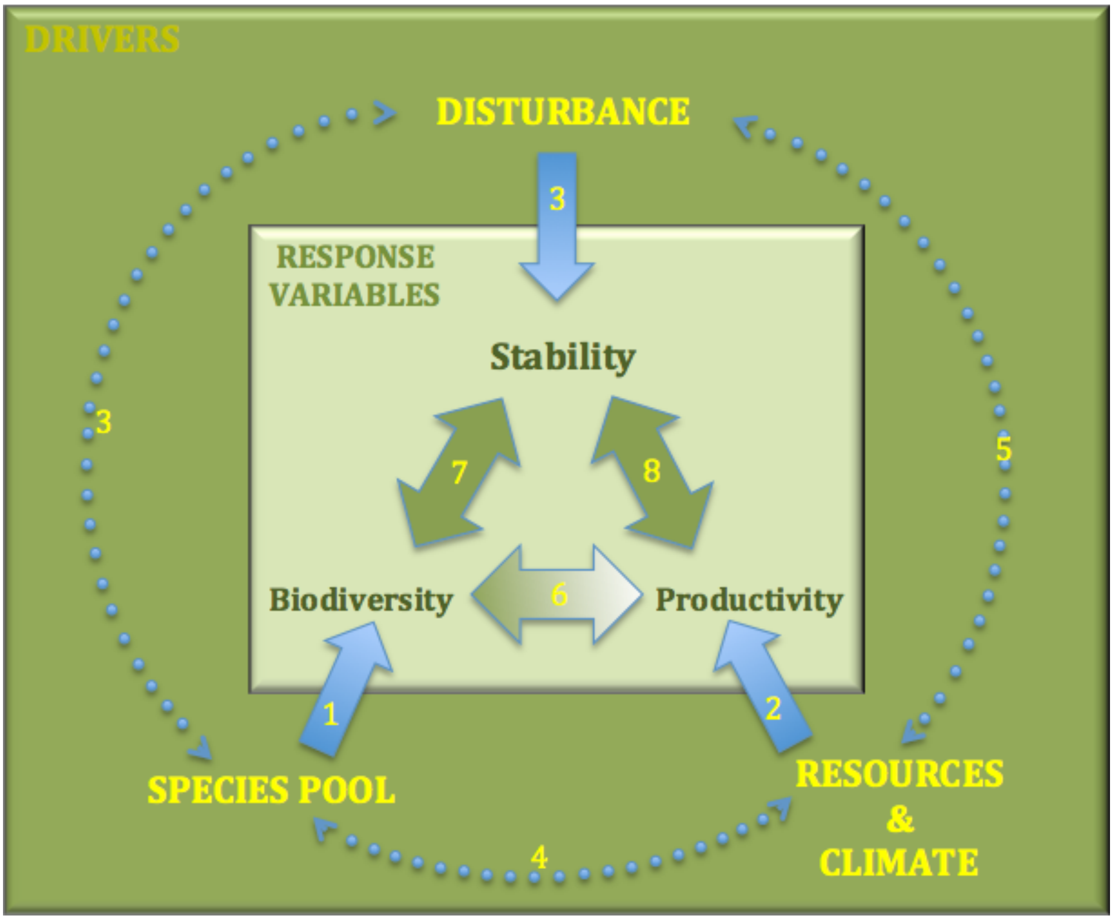


Figure 2. Social Systems conceptual model for Social Learning and Wellbeing

A Biodiversity-Stability Model



Conceptual models simply and transparently indicate our current level of understanding of how ecological systems work. They facilitate a systematic approach to identifying and evaluating appropriate on-ground management interventions. They help infer the causes of our field observations and the likely responses to our direct interventions.

Ecological restoration involves decisions primarily related to resisting or facilitating change. Whereas the conceptual framework published by Prober *et al.* 2011 is also helpful, it does not present a simple, overarching ecological systems model as does the above model.

The broad conceptual ecological model above is supported by nested sub-models to clarify, in more detail, states and processes occurring at finer spatial and temporal scales.

The model is based on that of Worm and Duffy (2003) and addresses drivers and response variables in ecosystem states and processes that affect overall stability (resistance and resilience).

The *drivers* of ecosystem change are represented in the dark green box; the *response variables* in the pale green box.

Resistance is defined as the capacity of the system to maintain community structure and function under stress and/or disturbance.

Resilience is the capacity to re-establish community structure and function *after* disturbance.

It is a biodiversity-stability model of ecosystem processes that recognizes ecosystems as:

i. complex, dynamic, spatially heterogeneous, and potentially exhibiting non-linear threshold dynamics;
ii. potentially existing in alternative stable states driven and maintained by bi-directional interactions and feedback loops between *drivers* (species, resources and disturbance regimes) and *response variables* (biodiversity, productivity).

Negative feedback loops are seen as the key to ecosystem stability providing resistance or resilience to environmental change (DeAngelis et al. 1986, DeAngelis and Post 1991, Work and Duffy 2003, Duffy 2009).

Positive feedback interactions are the key to ecosystem change between alternative stable states (either detrimental or desirable).

Bi-directional relationships exist between *biodiversity, productivity* — potential and realized carbon gain (6) and community *stability* —resistance, resilience (7, 8) with feed-back loops and indirect effects mediated by trophic interactions and other ecological processes including competition, facilitation, mutualism, herbivory and predation.

DRIVERS

Special Pool

The regional species pool is a primary driver of successional dynamics. The size and composition of the species pool is a function of filters operating from evolutionary to historical timeframes. Life-history traits of individual species determine what species can exist within a particular resource-climate-disturbance regime.

Resources and Climate

Resource availability (light, carbon, moisture, and nutrients) affect which species are able to establish at a site and their overall productivity and hence competitive abilities. Resource availability is affected by climate and processes affecting soil-water infiltration, retention, and release to plant roots, indirectly affecting nutrient availability.

Disturbance

Disturbance is any event or process (physical, chemical, biological) that diminishes or destroys biomass (hence productivity), such as fire, frost, herbivory, or management interventions such as mowing, herbicide applications etc., initiating successional processes.

RESPONSE VARIABLES

Biodiversity

Includes:

- species *richness* (number of species and functional groups);
- species *composition* (identity of species and functional groups;

Richness influences energy and nutrient fluxes (including carbon) through increased facilitation and niche complementarity at high species richness

Composition may affect productivity (6) through functionally dominant species which may only represent a small number of species out of the total regional or local species pool.

Other measures of *biodiversity* represent higher levels of diversity (communities) at landscape scales, or *phylogenetic diversity* reflecting evolutionary processes.

Productivity

Refers to both biomass production and potential productivity (realized and potential carbon gain) which reflects gradients in resource supply (energy, water, nutrients) (2). Increasing resource supply increases potential productivity (2) to which local diversity adjusts (6).

Stability

Stability is an emergent property of communities with respect to destabilizing influences (disturbance, stress) on community biomass.

Diversity increases stability (7) because of a greater range of adaptive functional traits within the species pool that keep productivity stable under a range of conditions.

Stability of the environment adjusts local richness within a species pool. A diverse community can stabilize the abiotic environment by ameliorating fluctuations in resource and conditions (water availability, ambient temperature) to influence disturbance regimes, thence diversity.

Key References

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SUMMARY OF GOALS (Ecological Outcomes)

Ten ecosystem attributes based on the SER International Primer on Ecological Restoration provide the basis for useful indicators to measure the success of restoration initiatives. An additional attribute (no. 2) relating to 'critical habitat' is included because the prime objective of the overall project is restoring World Heritage values and integrity.

1 The restored ecosystem contains the characteristic assemblage of species with community composition, structure and functions analogous with reference ecosystems

2 The restored ecosystem provides habitat for rare, threatened and significant species

3 The restored ecosystem comprises only indigenous species

4 All functional groups necessary for continued development, viability, health, resilience and evolutionary capacity, are present or able to colonize naturally

5 The abiotic environment can sustain reproductively viable populations of those species required for stability and resilience and continued ecosystem development along the desired trajectory

6 The restored ecosystem apparently functions normally for its ecological stage of development, and signs of dysfunction are absent

7 The restored ecosystems are suitably integrated into a larger ecological matrix or landscape with which it interacts through abiotic and biotic flows and exchanges

8 Potential threats to the health and integrity of the restored ecosystems from the surrounding landscape have been eliminated or reduced as much as possible

9 The restored ecosystems are sufficiently resilient to endure the normal periodic stress events in the local environment that serve to maintain the integrity of the ecosystem

10 The restored ecosystems are self-sustaining to the same degree as their reference ecosystems and have the potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of their biodiversity, structure and functioning may change as part of normal ecosystem development and may fluctuate in response to normal periodic stress and occasional disturbance events of greater consequence. As in any intact ecosystem, the species composition and other attributes of a restored ecosystem may evolve as environmental conditions change

SER 2004

Figure 3. Ten ecosystem attributes as the basis for monitoring ecological restoration effectiveness

All terms used in the description of goals are as defined in the SER International Primer on Ecological Restoration (2004). Attribute relationships are defined by a conceptual model of ecosystem function and stability that ARCS have adopted based on that described originally by Worm and Duffy (2003).

Monitoring the degree of achievement of the above attributes involves projects outlined in Table 1

Table 1. A summary of methods used to monitor achievement of defined Goals or Outcomes

Goals/Outcomes	Projects for monitoring defined outcomes
1. The restored ecosystem contains the characteristic **assemblage** of species with community composition, structure and functions analogous with reference ecosystems	**1a. Plant species assembly** (density, richness) is monitored directly in the field by marking and labelling all new plants in each 16.66 m x 16.66 m subcell that is part of a continuous grid, annually for most (**Project S2**), but seasonally in 15 subcells (**Project P1**). Values are corrected for mortality at each measure. Species identifications are by ARCS experts or by verification of voucher specimens against a reference collection. Data are collated and initially analysed using a FileMaker database, Excel spreadsheets or relevant analytical statistical packages. A proxy for advanced recruitment involves aerial photography (NearMap) and GIS-based quantitative, grid-based assessment of the increase in vegetation extent Plant density at fine scales, where applicable, is estimated from the number of individual plants per marked grid cell. **1b. Plant community composition/structure**: Trends in plant community composition and relative abundance are annually evaluated and based on seasonal monitoring of stratified quadrats compared with the previous years' results and with characteristic composition and abundance of indicator species in corresponding Reference Sites (Project SP4). Changes in plant community ***structure*** is monitored in 15 stratified quadrats by comparing changes in overall height, canopy dimensions, and leaf area index, summarised by height-classes differing by 20 cm up to 1 m, and by 50 cm increments thereafter to ≥6 m (Project P1). Heights are measured either with standard 1-m wooden rulers, Senshin Fibreglass Telescopic Height Poles (1-6 metres), or Haglof ECII clinometer (≥6 m); stem diameters with diameter tapes (larger trees) or calipers (≤10 cm). Data can be extrapolated to adjoining areas in order to predict their expected rates of change. In older communities basal area estimates by random or systematic point sampling using a wedge prism or factor gauge. Plant species assembly (richness) is monitored directly in the field by marking/labelling new plants annually in 16.66m x 16.66m sub-cells that are part of a continuous grid (Project S2). Values are corrected for mortality at each recording. Plant surveys (either transect-based or random wandering) are conducted for completeness of biodiversity inventories over larger scales. These include voucher specimen-based sampling. Specimens are identified fresh and/or after pressing and drying. Specimens are archived for reference in the ARCS professional-standard herbarium. Monitoring of World Heritage values and integrity is based on compliance with criteria in the WH Convention's Operational Guidelines and involves phylogenetic and biogeographic updates for taxa contributing to outstanding universal value. **1c. Animal and fungal community composition/structure**: (i). Targeted surveys and incidental observations (often associated with routine management activities) of mammals, birds, reptiles, and selected invertebrates (including snails, ants, dung beetles, earthworms). Survey of dung beetles involves live collection and release from pitfall traps, or counting density of dung beetle tunnels. (ii) Autonomous acoustic monitoring (Project S1) using an omnidirectional, high-powered microphone (Song Meter SM2 and SM3, Wildlife Acoustics Inc.), at 21 sites, set at sampling rates of 44.1 kHz and accuracy of 16 bits per sample. Identification to species and abundance assessment is by analysis of sonograms using specialist software (Songscope, Wildlife Acoustics Inc.). Reference sonograms of notes and songs for bird species total 748 individual records. (iii) Direct surveys of frogs utilise a range of omni- and uni-directional microphones and recording devices, e.g. H2nZoom Recorder (Zoom Corporation), Sound Devices 722 Field Recorder with Senheiser MKH70 and ME67 shotgun microphones at sampling rates of 44.1 kHz and accuracy of 16 bits per sample. (iv) Camera trapping involves secured, motion-triggered Reconyx HyperFire HC600

Goals/Outcomes	Projects for monitoring defined outcomes
	3.1 megapixel colour/IR cameras at key locations. Ltl Acorn 12 megapixel cameras (Ltl-5310) enabling both still and video recording are also used. SDHC memory cards are downloaded monthly. (v) Fungi surveys involve transects, incidental forays, and plot-based replicated sampling from wood, litter or soils using counts of fruit-bodies by species, drying and storing specimen, preparation of spore prints, and macroscopic examination, description and identification using stereo and/or compound microscopes. Ad hoc incidental sightings are useful due to the frequent presence of qualified individuals on a site including volunteers from Birds Queensland (Projects S2, BD6).
2. The restored ecosystem provides **habitat** for rare, threatened and significant species	Autonomous acoustic monitoring of bird and frog species (Project S1) allows detection of rare, threatened or significant species and their abundances. Standard observations (incidental records) provide valuable supplementary records. Plant species monitoring associated with routine marking and monitoring in Growth Plots (Project P1) and in other Grid cells on the site (Project S2). Life-history attributes of indicator taxa are documented, with information on distribution (including at Springbrook), habitat, ecology (general behaviour, feeding, reproduction), calls, taxonomic notes and phylogenetic significance, conservation status and threats, and management recommendations. Indicator reptile species include *Bellatorias major* (Land Mullet) and *Pseudechis porphyriacus* (Red-bellied Black Snake). Monitoring of World Heritage values and integrity is based on compliance with criteria in the World Heritage Convention's Operational Guidelines and involves phylogenetic and biogeographic updates on taxa contributing to Outstanding Universal Value (OUV) as defined.
3. The restored ecosystems comprises only **indigenous** species	Quantitative assessment of plant/plant part removals (by weight and number/subcell) provides confirmation of trends on repeated removal of non-indigenous species (**Project D7**). Semi-quantitative assessment of effectiveness of repeated removal effort via inspection (scale of 1–4) and photopoint moitoring of each subcell on the site (**Project P4).** Quantitative and semi-quantitative methods (subjective rating scale and photographic records) for assessing effectiveness and efficiency of removals as above (Project D7). Non-indigenous species are ranked according to their invasiveness potential (Batianoff and Butler 2002). *Setaria sphacelata* is controlled by mowing where interference with natural regeneration is not compromised, and by hand-shearing close to regenerating plants. Progress in suppression is measured by person-hours spent in either activity.
4. All **functional groups** necessary for continued development, viability, health, resilience and evolutionary capacity, are present or able to colonize naturally	The biodiversity surveys (Projects BD1–7) provide the basic information for assessing functional group integrity. Functional groups are defined by taxonomic, phylogenetic, morphological, and trophic classes; with subsets relating to niche specialization (resource, habitat, reproduction); as well as to fragmentation sensitivity (area- and barrier-sensitive; habitat specialist; dispersal-limited; metapopulation-dependent, otherwise ecologically important or phylogenetically significant)(Project BD9). Allied measures of taxonomic distinctness and phylogenetic diversity provide complementary indicators of diversity more allied to functional diversity and the influence of disturbance. Surveys of birds and frogs at some sites are restricted to incidental records and acoustic monitoring using omnidirectional, high-powered microphones (Song Meter), specialist software (Songscope, Wildlife Acoustics Inc. or Sound ID http://www.soundid.net/)(**Project S1**)
5. The **abiotic environment** can sustain reproductively viable populations of those species required for stability	**5a. Abiotic conditions — Microclimate**: (i) Seven ARCS micro-meterological nodes (Project RC1) sample parameters at 15 min intervals — rainfall, total and photosynthetically active radiation (PAR), air relative humidity (RH) and temperature (T), leaf wetness, soil volumetric moisture

Goals/Outcomes	Projects for monitoring defined outcomes
and resilience and continued ecosystem development along the desired trajectory	content and soil water potential. Additional nodes only sample PAR at 3 heights as a function of distance from forest edge to assess the impact of shading on diameter increments. (ii) The wireless sensor network (Project RC2) involves 175 nodes placed at 50 m-intervals along 10-m contours. The nodes were developed by the CSIRO. The ecological design (type and location of sensors; location of nodes) of the network was by ARCS. Monitoring elsewhere as required is by using a Kestrel 4500 Pocket Weather Meter with comparisons to adjacent cleared areas with formal weather stations. Micrometeorological monitoring is extrapolated to nearby analogous environments where nodes are not located. **5b. Abiotic conditions — Soil and litter health** Soil health assessments are conducted as part of Project RC3. Soil compaction and moisture levels are considered a minimal set of surrogate indicators of soil health at a broad scale (Other physical parameters measured on more limited stratified quadrats include depth, texture, pH (Kelway Soil pH Meter), dispersion and colour). Soil colour is based on Munsell Colour charts. Transect-based measure of soil compaction is done using a drop-cone penetrometer (model based on the Jornada design and fabricated locally for ARCS); soil moisture other than at micrometeorological stations is measured using a portable MPKit (ICT International). Earthworm activity (a key bioindicator including of soil organic matter) is semi-quantitative (counts per unit area dug) but non-lethal, non-invasive soil imaging methods are being investigated. Leaf litter levels are measured by a steel prong capture method. Macrofungi surveys in transects and stratified quadrats (Project BD2) are indicative of soil health and successional development. The method chosen depends on the nature of the substrate and site generally.
6. The restored ecosystem apparently **functions** normally for its ecological stage of development, and signs of dysfunction are absent	System processes (functions) relevant to monitoring of restoration are at the level of individuals (physiological), populations (demographic), ecosystems (biogeochemical cycling, soil-water fluxes, biotic interactions) and the landscape (hydrological, fire regimes, geomorphic processes and species movements). Key processes relating to species interactions including competition, mutualism, facilitation, predation and herbivory are considered in project activities (Projects SP1–4).
7. The restored ecosystems are suitably integrated into a larger ecological matrix or landscape with which it interacts through abiotic and biotic flows and exchanges	**Canopy Cover (surrogate for functional connectivity)** Aerial photography (NearMap) and GIS-based quantitative, grid-based assessment of canopy cover to determine extent of connectivity recovery in key bottleneck areas. NearMap high resolution images are available commercially at varying time intervals (18/1/2011, 19/6/2011, 21/7/2011, 9/11/2011, 14/6/2012, 5/8/2012). Estimates of Leaf Area Index (LAI) and effective plant biomass outside the growth plots using a portable ceptometer (AccuPAR LP-80, Decagon Devices Inc.) provide a measure of average canopy density based on degree of light transmission. Alternatively, fine-scale assessments are carried out using pointy sampling with a Spherical Crown Densitometer or line-point transect sampling with a GRS Densitometer. The latter method allows greater characterisation of forest structure in addition to canopy closure levels.
8. Potential **threats** to the health and integrity of the restored ecosystems form the surrounding landscape have been eliminated or reduced as much as possible	Threats are categorized into groups relating to which aspect of the ecological conceptual model is affected (Projects D1–10): (a) Species pool effects: insufficient ecological resources to restore and maintain viable populations: introduced plants, fungi, animals; (b) Resources-climate effects: altered biogeochemical processes affecting critical nutrient and resource levels or altered soil or above-ground condition (c) Disturbance regime effects: fire, frost, climate change, disease etc (d) Species interaction imbalances or losses (trophic or non-trophic)

Goals/Outcomes	Projects for monitoring defined outcomes
	Threats associated with social systems strongly focus on: (a) Governance deficiencies (b) Social learning impediments to paradigm shifts
9. The restored ecosystems are sufficiently **resilient** to endure the normal periodic stress events in the local environment that serve to maintain the integrity of the ecosystem	**Ecosystem stability (resistance/resilience)** Our broad- and fine-scale ecological conceptual models provide the basis for assessing emergent system dynamics that consider the necessary elements contribution to resistance/resilience — the drivers of environmental change (species pool characteristics, climate, resource fluxes, disturbance regimes), and site response variables (ecosystem structure and processes, including system seed banks that might stabilise/destabilise alternative stable states) (Project S3) A resilience model directs monitoring experiments for assessing drivers and response variables affecting ecosystem dynamics and potential for sudden, essentially irreversible change in ecosystem states (Project S3). Monitoring variance in the degree of shading in quadrats using a portable ceptometer (AccuPAR LP-80, Decagon Devices Inc.) is deemed a strong proxy for detecting potential switches in states. Macrofungi surveys in stratified quadrats (Project BD2) are expected to provide long-term indicators of soil health and successional development.
10. The restored ecosystems are **self-sustaining** to the same degree as their reference ecosystems and have he potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of their biodiversity, structure and functioning may change as part of normal ecosystem development and may fluctuate in response to normal periodic stress and occasional disturbance events of greater consequence. As in any intact ecosystem, the species composition and other attributes of a restored ecosystem may evolve as environmental conditions change.	**Self-sustaining ability** Ecological measures of sustainability include: Attainment of reproductive maturity and reproductively viable population size of members of key functional groups. These are long-term metrics and do not apply until 10–20 years into the project (data are derived from the range of 35 formal projects) Economic measures: when the costs of ongoing management do not exceed those of mature undisturbed ecosystems. All activities associated with the project are timed and costed to be able to assess management effectiveness, efficiency and, in part, project completion (Projects R1, R2)

Individual Projects