MONITORING BIODIVERSITY IN SOUTH-WEST FORESTS

Concept Plan

Draft of 24 September 2001

Science Division

Department of Conservation
Government of Western Australia

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Executive Summary

1. ESFM is well defined at a policy level but remains an ill-defined scientific concept.
2. FORESTCHECK is a framework devised in 1999 to quantify, record, interpret and report on the status of key forest organisms, communities, and processes in response to both forest management activities and natural variation.
3. A CALM Implementation Group has been established to guide the development and implementation of FORESTCHECK.
4. The most desirable attributes have been identified as simplicity, integrated sampling, efficient sampling, reliability, feasibility, credibility and affordability. It is recognized that it is not possible to optimise all of these traits simultaneously.
5. Monitoring is treated as a form of quality control. FORESTCHECK is not a substitute for audit, compliance, survey or research.
6. FORESTCHECK has been designed to mesh with the Montreal Process Criteria and Indicators (agreed to jointly by the Commonwealth and State Governments in 1998).
7. This concept plan has been workshopped within CALM (April 1999) and with scientists from universities, CSIRO, and the WA Government, as well as scientists privately employed (October 1999, March 2000).

Introduction

Monitoring, audit, compliance and research are terms widely used at present in corporate governance in Australia. The first three concepts refer to the checking process in the sequence PLAN - ACT - CHECK. Audit until recently referred to the official examination and verification of (orally presented) financial accounts by an independent body. It is often used now to refer to independent verification of any matter, particularly systems in place. Compliance refers to the need to check how well an action adheres to stated policies, prescriptions, codes of practice etc. Monitoring is also a form of quality control, but includes the concept of testing at intervals in relation to achievement of nominated objectives. By contrast, research alludes to systematic and critical investigation to discover facts and reach novel conclusions and thereby create new knowledge. Scientific research is generally pursued within a framework of formulating and testing a set of hypotheses. It is important to recognize that monitoring, while methodical, is neither scientific research nor a substitute for it. Nevertheless, monitoring is underpinned by scientific knowledge and its results may assist in the generation of hypotheses; these can then be addressed using scientific methodology.

Because knowledge about disturbance ecology is incomplete, monitoring is likely to generate data that are open to interpretation in some cases. Expert scientists can contribute to the interpretation of the data acquired. Ultimately, it is most important that the forest owners, the Western Australian community, understands and accepts the consensus of expert opinion, and takes this into account when making social and political decisions about ESFM.

ESFM includes delivery of economic, social and environmental outcomes, Environmental monitoring via FORESTCHECK is just one aspect of the ESFM process. Collectively, these three components will facilitate changes to forest management practices so that the community obtains from forests what it seeks.

Monitoring in the southwest forests of WA commenced in 1916, with the establishment of plots to measure growth rates of trees. Other significant events in monitoring focused on mammals and fire impacts (1972). These and others are itemized in Attachment 1.

Compliance and monitoring are not new concepts, as evidenced by the venerable learning technique of trial-and-error (involving an action, then its assessment, followed by correction if an unwanted outcome resulted). The main difference between trial-and-error learning and more sophisticated versions lies in the degree of formality involved with the latter. Expected outcomes will be declared from the beginning in a written plan, there will be records of what actions were undertaken and when, where and how they were done. After implementation, there will be written records of how well the action was performed in relation to the declared expected outcome. If all proceeded 'according to plan' there is no need for corrective action and the principle of 'management by exception' is followed. If, however, there are 'surprises' (unexpected outcomes) or failure (the expected outcome wasn't produced), the planning process has to re-commence. The process is necessarily iterative.

This approach has become subsumed in the last 20 years under the concept of adaptive management, in which management interventions are regarded as hypotheses to be tested by implementing the planned action and following up subsequent events ('learning by doing').

In 1988 CALM approved a formal monitoring policy. This, however, proved unimplementable because of logistic reasons, resource limitations and lack of an agreed focus in the policy. It was formally withdrawn subsequently.

The current Forest Management Plan (LFC 1994) also committed to use of monitoring (pp. 51-52):

> *Implicit in the undertaking of management action is the need to monitor the implementation and impact of those operations. Monitoring is important across the full range of management actions, e.g. use of a recreation site or how closely a burn achieved its prescribed intensity, because through it the success of meeting forest management objectives is evaluated and the opportunity to upgrade prescriptions is presented.*
>
> *CALM's research programs also provide continuous input to the management process. The research programs are periodically adjusted to ensure they are providing information of the most important strategic value.*
>
> *At the most fundamental level CALM's forest management objective is to preserve biological diversity and the ecological processes which sustain that diversity. Monitoring to check if that is being achieved is difficult, because natural changes in ecosystems interact with those caused by management-related disturbance and because the large number of ecosystem components all react differently. A comprehensive monitoring program will encompass three components of ascending complexity, as follows:*
>
> ***(a) Monitoring the effectiveness of measures to protect the environment***
>
> *Codes of practice are the guidelines used to control forest operations in the field. They set standards and measures of performance for activities and operations conducted by CALM, contractors and other users of public forests.*
>
> *These codes aim to ensure that the people carrying out a forest operation such as road construction, tree planting, timber harvesting or recreation site maintenance complete it to the highest standard existing knowledge allows. They therefore constitute current best available practice.*
>
> *"Codes of practice" collectively describe a range of documents including manuals, prescriptions, specifications, standards and Guidelines. The codes are one of the instruments used to set standards for forest operations. Acts of Parliament, regulations, policies and contracts are other instruments used for this purpose.*
>
> *CALM uses codes of practice for each of the major activities and operations conducted in the forest regions. Codes are reviewed and re-issued annually to reflect the results of the year's monitoring, or new research information.*

Responsibility for implementing the codes is assigned to CALM's regional and district staff, assisted as necessary by specialist branches. Specialists and regional staff also have a role in ensuring that prescriptions are correctly followed in the field.

(b) Monitoring the impact of disturbance-causing activities.

In CALM this is carried out primarily through the Department's research program. Clearly, all species of the biota cannot be studied, and research is concentrated on what are believed to be keystone species.

Species known to be rare or under threat are given special emphasis in research, and in operational planning procedures. Threatened flora management programs will be progressively developed and implemented.

(c) Monitoring ecosystem change through periodic measurement of an extensive system of permanent plots and selected vertebrate and invertebrate species.

This is the most sophisticated level of monitoring because, if done adequately, it measures baseline ecosystem health and can detect management-induced change or natural environmental changes. It is, however, very difficult because:

- *it requires considerable initial research to obtain a good dataset of regional biota;*
- *a large number of plots must be established and enough organisms sampled to ensure environmental diversity is covered.*

Within the forest regions (a) is implemented, (b) partly implemented and (c) yet to be initiated. As resources allow, the monitoring program will be steadily upgraded through sophistication of (b) and, finally, full implementation of detailed ecosystem monitoring.

In recent years these impediments have been largely resolved because of significant advances in technology, information and concepts.

First, the tool of GIS has become more sophisticated and also more readily available as a result of huge increases in computer capacity.

Second, the information base for the southwest forests has greatly expanded, largely because of the Regional Forest Agreement (RFA) process. All available fundamental data have been captured electronically (with one major exception, fire history, currently being addressed).

Third, the conceptual distinctions between strategic research, prescription, and monitoring have become clearer. The strong conclusions from soundly-based research when incorporated into prescriptions obviate the necessity for frequent or detailed monitoring. This permits better deployment of available resources so that time and money are not wasted on documenting the obvious or monitoring an action that already has sufficient safeguards built in.

Finally, nations with temperate forests have committed to a process (the Montreal process) that uses agreed criteria and indicators to assess ecologically sustainable forest management. This protocol developed from the 1993 Convention of Biological Diversity held in Rio de Janeiro and was agreed to by the Commonwealth of Australia and the States in August 1998 (Anon 1998). The agreed phased implementation of indicators is outlined in Attachment 2. FORESTCHECK will contribute to indicators 3.1a, 1.2c, 3.1c and 4.1e. Some possible indicators of ESFM in jarrah and karri forests and other southwest forest ecosystems are tabulated in Attachment 3.

When the Minister for the Environment approved the Forest Management Plan, he set a number of Ministerial Conditions that CALM had to address. Those relevant to monitoring are:

3-1 The proponent shall manage karri and karri-marri forest in accordance with a precautionary approach. This approach requires that where there is a significant risk that a particular forest management measure could lead to an irreversible consequence, appropriate monitoring and subsequent adjustments to management within an acceptable time-frame be carried out.

3-2 The proponent shall manage the jarrah forest in accordance with the following general principles:…

(2) adaptive and flexible management practices based on research and monitoring of environmental monitoring of operations…;

5-3 The proponent shall monitor the effectiveness of the travel route (road) river and stream reserves for nature conservation and protection of water quality to the requirements of the Minister for the Environment.

11-1 The proponent shall implement the jarrah silvicultural prescription so that the monitoring of the environmental impacts on a representative range of treated sites and localities in the forest can be carried out to the requirements of the Minister for the Environment. This shall include long term monitoring which quantifies the impacts of silvicultural practices on environmental elements and values in the forest and provide bases to adjust management.

12-3 The proponent shall monitor, to the requirements of the Minister for the Environment, and report by 2002 on the status and effectiveness of these measures to protect nature conservation values and water quality at the time of the next review of the Forest Management Plans and Timber Strategy.

In signing the RFA, the WA Government agreed to:

42. Within 5 years of the date of this Agreement, Western Australia will further improve its Forest Management System and processes through the development and implementation of environmental management systems in accordance with the principles specified in Attachment 13 and the actions identified in Attachment 5 and acknowledges that its objective for native forest management under the CALM Act is system certification comparable with ISO 14000 series. The Parties note that such a system would include independent auditing of compliance with Codes of Practice and the Forest Management Plan.

46. Western Australia will report on the results of monitoring of sustainability indicators as part of each 5 year review and report in accordance with Clauses 36 and 37.

47. Comprehensive Regional Assessments, the development of criteria and indicators for sustainable forest management through the Montreal Process and the development of this Agreement have provided extensive opportunities for public participation and reporting. Parties note the range of reporting and consultative mechanisms that currently exist in Western Australia (see Attachment 4) and agree that Western Australia will further develop these by implementing the improvements specified in Attachment 4.

51. The Parties agree that the current Forest Management System will be enhanced by further developing appropriate mechanisms to monitor and review the sustainability of Forest management practices. To ensure that this occurs, in consultation with the Commonwealth, the State agrees to establish an appropriate set of sustainability indicators to monitor Forest changes. Any indicators established will be consistent with the Montreal Process Criteria (as amended from time to time), the current form of which is specified in Attachment 7, and will take into account the framework of regional indicators developed by the Montreal Process Implementation Group. Western Australia will implement those indicators, which are practical, measurable, cost-effective and capable of being implemented at the regional level and will monitor them at an appropriate frequency determined in consultation with the Commonwealth.

52. *Development of indicators, and collection of results for those indicators, which can be readily implemented, will be completed in time to enable reporting during the first five-yearly review of this Agreement.*

Purpose of FORESTCHECK

FORESTCHECK is intended to serve as a framework to quantify, record, interpret and report on the status of key forest organisms, communities and processes in response to both forest management activities and natural variation. Monitoring is an essential part of systematic best practice management in order to achieve the objective of ESFM. FORESTCHECK will provide relevant information to judge whether forest biological diversity is being sustained indefinitely, part of the overall objective of the 1994 Forest Management Plan (LFC 1994).

Proposed conservation objectives for forests

The maintenance of biodiversity and of the ecological processes upon which it depends is fundamental to the notion of ESFM. Setting forest biodiversity conservation objectives is not straight forward because of the complexity of biodiversity through space and time and because knowledge of biodiversity and disturbance ecology is incomplete. Notwithstanding this, having clear conservation objectives for forests is of key strategic importance. It will assist with setting silvicultural objectives and standards, with determining sustained yield and with assessing the acceptability or otherwise of the environmental impacts of logging as they are understood from the research and monitoring. The following is a proposed hierarchical set of conservation objectives for forests for consideration. These objectives should complement (rather than replace) existing codes of practice and silvicultural objectives. An important strategic issue for the Department is the resolve with which conservation objectives are set. For example, should the objectives explicitly state that '*no species will become extinct as a result of management activities*', or should the objective be '*to take all reasonable measures to ensure that no species become extinct*'?

At the landscape scale: A definition of a landscape:
"A mosaic where the mix of local ecosystems and landforms is repeated in a similar form over a kilometres-wide area. Several attributes, including geology, soil types, vegetation types, local faunas, climate and natural disturbance regimes tend to be similar and repeated across the whole area" (Forman 1995).

Bio-physically-based amalgamations of the Mattiske & Havel (1998) vegetation complexes form a basis for identifying forest landscape units.

Landscape scale conservation objectives:. *Take all reasonable measures to:*

- *Ensure that no species declines to irretrievably low levels as a result of forest management activities.*
- *Ensure adequate reservation of forest landscapes.*
- *Ensure a diverse representation of forest structures/habitats and seral stages through time and space with an interlocking mosaic of patches of forest at different stages of development including new growth and old growth stages.*
- *Protect ecologically sensitive areas and niches such as riparian zones, aquatic ecosystems, wetlands, granite outcrops and other non-forested complexes.*
- *Ensure maintenance of water quality.*

At the forest patch scale: A definition of a forest patch:
A spatial element within a landscape. It could be a (sub) catchment or a mapped management boundary, such as a forest block - it could contain a representation of landforms and ecosystems common to the landscape unit.

Forest patch (block) scale conservation objectives*: To take all reasonable measures to:*

- *Ensure that biodiversity (species richness) has recovered before the next cutting cycle.*
- *Ensure that the capacity of the block to provide the range of habitat elements that it provided before logging is not permanently compromised due to logging and associated activities.*
- *Ensure at least 20% (including road and stream reserves) of the forest block retains mature or old growth overstorey structural characteristics.*
- *Prevent the introduction and spread of dieback.*
- *Minimise the introduction and spread of weeds and other aliens*

At the coupe scale*:* A definition of a coupe:
An area contained within a cutting boundary (a gap or area cut to shelterwood or thinned).

Coupe scale conservation objectives*: To take all reasonable measures to:*

- *Ensure recovery of biodiversity (species richness) before the next cutting cycle.*
- *Prevent soil erosion*
- *Minimise soil damage (compaction, profile-mixing, puddling).*

Threatened / listed taxa: These have legislative protection:

- To take all reasonable measures to protect (retain at viable levels) all populations of threatened/listed taxa/communities. (note: viable population levels will be unknown for most species – scientists will need to provide 'best bet' in absence of hard data).

These goals form the basis of more detailed monitoring objectives, involving all species of vertebrates and vascular flora (abundances), a selection of microbiota (invertebrates and macrofungi), and several practical measures of ecosystem processes relating to soil, water, vegetation growth, and foliage. Because microbiota are mostly unnamed and few species have been studied, it is necessary to focus on those groups for which some pertinent information is available. Similarly, ecosystem processes operate at many different spatial and time scales and have not yet been analysed comprehensively by scientists. Hence it is necessary to monitor those attributes that are relevant but inexpensive to measure.

Monitoring is not experimental research. Monitoring is intended to track management performance over large space and time scales in relation to stated goals, whereas experimental research is to discover the causes of observed phenomena. Monitoring serves management by demonstrating long-term trends in the performance of measured attributes. If such trends are downwards or slow to improve, management is then alerted to the need to conduct investigations, which may include experimental research.

FORESTCHECK is a simple, practical, credible and integrated system that will satisfy (over time) a number of requirements, namely Ministerial Conditions, RFA, the biological subset of Montreal Process criteria and indicators of ESFM, a more generalized retrospective study, Western Shield monitoring in forests, and validation of vertebrate surveys in forest blocks by P Christensen and G Liddelow.

Phase I of FORESTCHECK is intended to satisfy Ministerial Conditions applied to the 1994 Forest Management Plan (jarrah silvicultural systems). Phase II will involve a sophisticated retrospective analysis of historical disturbance information and assess the impact of disturbance across many taxa and a wider range of forest ecosystems. Phase II awaits the conversion of 60 years of fire records from microfiche to GIS and is not considered further in this document.

FORESTCHECK deals only with monitoring. Compliance of Departmental operations with policies, prescriptions, codes of practice etc. is addressed elsewhere in CALM through Management Audit Branch.

Proposed structure of FORESTCHECK, Phase I (jarrah silvicultural systems)

FORESTCHECK will be based on fundamental environmental and disturbance themes:

a) Landscape conservation units in the RFA area (Christensen *et al*. 2001). It is expected that only a few of the 52 units mapped will cover most logging operations pertaining to the Ministerial Condition.

b) Logging since 1990 under the 2 main silvicultural systems (gap release, shelterwood), of the 7 systems currently in use.

c) Recent forest fire history
This information is available in GIS.

Therefore, a FORESTCHECK site will have attributes in relation to a landscape conservation unit, a logging history, and a prescribed burning history. Sample plots will be located in various disturbance classes (shelterwood, gap release, coupe buffer not recently logged, external reference forest) within a FORESTCHECK site, which will be replicated.

Few existing sites for which adequate biological information is available (Water & Rivers Commission sample sites, existing growth plots, botanical sampling sites established for the RFA, Western Shield monitoring sites, experimental catchments, etc.) align with proposed FORESTCHECK sites. This reinforces the need for a better integrated system for monitoring the forests of south-west Western Australia.

Landscape conservation units were selected as the appropriate framework for study. Forest ecosystems (Bradshaw et al. 1997) are too coarse (27 units) and vegetation complexes (Mattiske and Havel 1998) are too fine a resolution (>300 units).

The following principles have been adopted:

i) Because of the spatial and temporal scale involved and the vast number of plant, invertebrate and fungal species present in forests, simplicity will be favoured over complexity e.g. ordinal data, counting only of indicator species, presence [= recorded] / absence [=not recorded]. Quantified measures of abundance will, however, be made of vertebrate species.

ii) Unlogged or lightly logged reference sites (controls) will be selected to serve to distinguish natural change from imposed change.

iii) The unit of study (a FORESTCHECK site) will be at the landscape scale of 10-100 ha, consisting of several disturbance types in close proximity.

iv) Where there is sufficient information, indicator species will be selected to maximize contrasts in functional ecological traits (vital attributes), e.g., mobility (dispersal capability), home range, time to first flowering/fruiting (obligate seeders with long juvenile periods, obligate seeders dependent on canopy-stored seed), slow-growing perennials subject to mechanical destruction, *Phytophthora*-vulnerable taxa, plants acting as substrates for cryptic and other epiphytes where the epiphyte requires mature hosts, summer/autumn flowering species, fecundity, trophic position, nesting substrate, feeding substrate, degree of specialization), taxonomic position (e.g. with reference to the Five Kingdom concept of Margulis & Schwartz 1988), and status (e.g. Declared Rare Flora). A balanced array of sensitive and robust species will be selected. Refer to Attachment 3.

v) Sampling will be at the patch level (up to 10 ha), so that data can be aggregated to the landscape level.

vi) Ecosystem processes such as nett primary productivity, nutrient and water cycling, and energy transfer cannot usually be monitored directly because of insufficient knowledge or logistic impediments. These processes will thus be approximated by key habitat attributes, e.g. litter depth (for soil organic matter), stand basal area (for tree growth and salinity), turbidity in higher order streams, compaction, and foliar nutrients.

vii) Biodiversity (here treated as species richness as a necessary simplification) will be calculated for all vertebrate and plant species present, but only for selected groups of invertebrates and fungi.

viii) Some groups or topics for which knowledge is deficient, will need to be studied initially by way of special research effort, e.g. bats, locally endemic invertebrates, substrate-dwelling and other freshwater invertebrates, soil carbon.

Some attributes cannot at present be sampled directly because of inaccessibility, e.g. canopy arthropods (25-30m above ground level).

Sampling design

The major elements of each monitoring site are as follows:

1.	Landscape conservation unit	Initial emphasis will be placed on those units in which most logging in the 1990s has taken place.
2.	Logging disturbance	2 timber harvesting methods, identified as % of stems retained, and 2 reference types, not logged in the 1990s [coupe buffer, in a road or stream reserve; the other in adjacent recently unlogged or lightly logged forest].
3.	Time since logging	Areas logged in 1990, 1995 and 2000 will provide snapshots of forest 10, 5 and 1 years after logging.

In addition, where there is a strong topographical contrast, such as close to the Darling Scarp, a ridge/valley comparison will be included.

It is envisaged that FORESTCHECK will eventually consist of about 30-40 monitoring sites.

Because FORESTCHECK is the monitoring component of an adaptive management approach, and is not a scientific experiment, we are not attempting to align the Department's prescribed burning program with FORESTCHECK sites. Prescribed burning usually follows within 2 years of logging, and then recurs some 5-10 years later, dependent on fuel accumulation ratio, on burning days available and human resources. Records of all prescribed burning operations will be kept so that recovery of indicators following fire can be tracked. Over time the impact of fire will be able to be factored out. Phase II of FORESTCHECK will examine much more systematically the effect of various fire regimes on biodiversity.

Harvesting treatments will be assessed as level of impact (tree cover, basal area retained) in the categories gap, shelterwood etc. Some sites may not have all treatment categories present.

Sampling frequency will need to be flexible. It is unlikely that sufficient resources will be available to re-sample monitoring sites more frequently than 5-10 years (longitudinal study). Sampling in the first year will provide the necessary short-term retrospective focus of 1-10 years since logging.

Hypothesis testing, false positives, false negatives, and statistical power

Hypotheses cannot logically be proven correct, as inability to invalidate a hypothesis does not necessarily prove it to be true. However, incorrect hypotheses can be demonstrated to be false. For most of the period since the rise of physical science as a discipline of rigorous inquiry, the least preferred outcome has been that of the false positive, where an untrue connexion between two factors as cause and effect has been accepted as correct (Type I error). In environmental science, however, the false negative (where a lack of an impact is wrongly accepted as correct, Type II error) potentially has irreversible consequences through the continuance of the threatening process.

In any monitoring study, it is important to consider statistical power. In simple terms, statistical power encapsulates the obvious notion that a study must be sufficiently replicated to give reasonably precise estimates of the measured parameters. In monitoring, where comparisons are often made between a 'control' and 'impact' treatment, this precision must be sufficient to detect any biologically important differences. If a variety of organisms are to be monitored, varying levels of replication may be needed for each in order to accommodate their different levels of variability.

An important aspect of power analysis is that it enforces an explicit consideration of effect sizes and specification of null and alternate hypotheses. In monitoring, these hypotheses are:

H_o: The mean for the disturbed site is equal to the mean of the reference site.
H_a: The mean for the disturbed site is greater than or less than the mean of the reference site.

In H_a, the one-sided alternatives may be appropriate for some organisms where the form of the response to disturbance is known. The effect sizes are the degree to which differences between the treated and reference sites are deemed of biological importance. Thus, for one species the criterion may be that its abundance be >90% of that at the reference site. For another, it may be that it is present at the same proportion (within 5%) of disturbed, as at reference, sites.

However, determining what constitutes 'sufficient' replication prior to commencing a study is difficult. Many studies have found that *a priori* power analysis is so inaccurate as to be almost worthless, leading some to argue that power analysis itself is irrelevant (Green 1994). Research conducted on forest birds birds (M Craig PhD thesis study at Kingston and Williams *et al*. Gray karri bird study) and invertebrates indicates that the analysis of variance approach for individual taxa fails because the large number of replicates required is far beyond the resources available.

For these reasons, analytical techniques that do not depend on power will be favoured initially. These are multivariate techniques that examine changes in community structure rather than in individual taxa.

Sampling methodology

The major constraint in designing sampling protocols is the 10 ha size of forest cut to gaps. If plots or grids are too large, the buffer area will be compromised and any effects due to treatment will thus be confounded.

Treatments are defined as forest that is either shelterwood, gap release, coupe buffer or unlogged controls. Each FORESTCHECK site will be assessed at 2-5 yearly intervals, depending on availability of resources and time since disturbance, with more regular assessments soon after disturbance. Outputs and estimates of the time taken to complete fieldwork at a FORESTCHECK site are provided in the Operating Plan.

Responsibility for data interpretation

There will be an ongoing need for research scientists to provide advice, training, and to assist with the interpretation of outputs.

Data management

Standardized corporate databases will be set up prior to fieldwork. These will determine the recording sheet for each taxon/attribute. Once data are collected, they will require processing, management, maintenance, integration and distribution. These processes are critical to the success of FORESTCHECK. The Co-ordinator and Technical Support officer will be responsible for vouchering of specimens and the co-ordination, analysis, interpretation and initial reporting of the data collected. Details of reporting procedures need to be developed in consultation with the Conservation Commission and Director of Sustainable Forest Management in the new Department of Conservation.

Public consultation and community involvement

A workshop involving CALM personnel was held in April 1999 (Attachment 4) to discuss the framework of a forest monitoring system. A CALM Implementation Group was then established (Attachment 5). The role of this group has been to guide the development of a monitoring protocol (FORESTCHECK). The resulting draft concept plan served as the basis of an external workshop held in October 1999. This was attended by 22 scientists not employed by CALM (Attachment 6). They were asked to address several issues, particularly to consider the strengths and weaknesses of FORESTCHECK, to suggest improvements to sampling design and methodology, and to provide advice on the interpretation and presentation of monitoring data. A second workshop was convened in March 2000 to address monitoring protocols and interpretation of outputs, issues that were not resolved at the first workshop. Twenty-six invitees participated in the workshop (Attachment 7). These suggestions have been used to produce this revised version of the concept plan. A summary of advice not adopted has been sent to all participants in these workshops. This summary is at Attachment 8.

It is proposed that occasional field days be held periodically in each CALM District. Interested members of the public (e.g. university students) can then participate in data collection; this may also lead to a corps of volunteers willing to assist regularly in the collection of data. This will increase the visibility of FORESTCHECK with the public. In addition, it is intended that FORESTCHECK should feature on CALM's NatureBase site (http://www.calm.wa.gov.au).

Interpreting the results

FORESTCHECK concentrates on only some aspects of ESFM and as such can not be expected by itself to guide changes to forest management consistent with ESFM. In addition, the relative importance of specific forest values depends on community expectations that vary. Hence, what constitutes sustainable forest management will vary depending on the nature of the forest and community expectations.

Nevertheless a key challenge is to interpret change in measured variables after imposed disturbance and to decide when the trajectory of recovery during a particular period warrants consideration of change to management practices. FORESTCHECK will provide information relevant to determining recovery periods, recovery patterns and patterns in variation through time. For invertebrates and fungi, knowledge of recovery of biodiversity is minimal.

The recolonization by birds of the regenerating forest on a clearfelled karri coupe in Gray block (illustrated in Fig. 1) is provided as a real example of the type of data that will be collected by FORESTCHECK. These data show that the avifauna is "on track" in terms of the recovery trajectory.

Three broad types of output are envisaged. Trajectory graphs similar to those in Fig. 2, with standard errors of the means calculated as data accrue, will show the extent and rate that biodiversity, indicator species, and other attributes return to levels comparable to reference sites. Calculation of 95% confidence intervals will permit valid statistical comparisons. Where there are regular monotonic trajectories it may be practical to fit equations (as in Fig. 1). The second output will be ordination analysis of assemblage data (species composition), using non-metrical dimensional scaling (based on abundance data) or similarity coefficients (based on presence/absence of species). For an example of the former, see Fig. 3. The third output is a profile diagram, showing the proportion of treatment sites at which species have been recorded. When the species are sorted in order of their frequency of occurrence in reference sites, it is straightforward to determine which species have recovered in treated sites. Fig. 4 shows an example taken from Alford and Richards (1999).

Management of FORESTCHECK

There may be merit in seeking external membership on this group.

Outcomes from FORESTCHECK

In addition to making a significant contribution to forest science and to ecologically sustainable forest management in Western Australia, FORESTCHECK will provide a framework for meaningful public participation in forest management and will deliver relevant information to satisfy the following obligations:

Ministerial Condition 5.3 (part):	Turbidity, salinity, freshwater invertebrate indicators.
Ministerial Condition 11.1:	Vertebrate, invertebrates, plants, fungi indicators, litter depth, soil organic matter, soil bulk density.
Ministerial Condition 12.3:	Vertebrate, invertebrates, plants, fungi indicators, litter depth, soil organic matter, soil bulk density.
RFA 42.	Vertebrate, invertebrates, plants, fungi indicators, litter depth, soil organic matter, soil bulk density.
RFA 46.	Vertebrate, invertebrates, plants, fungi indicators, litter depth, soil organic matter, soil bulk density.
RFA 47.	Consultative mechanisms and public reporting.
RFA 51.	Montreal process criteria/indicators.
RFA 52.	Montreal process criteria/indicators.

As data accrue, modelling of the distribution of species will become possible.

Time line

March 99	Science Management Council endorsement of draft Integrated Forest Monitoring System concept plan
April 99	CALM workshop of concept plan
May 99	Present revised concept plan for approval by Corporate Executive
Aug 99	First meeting of Implementation Group
Oct 99	Hold workshop with external experts
Nov 99	Revise document for further scientific scrutiny
Mar 00	Hold workshop with external experts to finalize protocol
May 00	FORESTCHECK concept plan approved by Corporate Executive
Jun 01	CALMScience Division workshop of operating plan
Nov 01	Commence installation of FORESTCHECK sites
?Dec 03	Report on Ministerial Conditions

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ATTACHMENT 1

MILESTONES IN RESEARCH AND MONITORING IN THE SOUTHWEST FORESTS OF WESTERN AUSTRALIA

1842	First vertebrate specimens collected for scientific study
1890	First publication on the forest avifauna
1916	First growth plots for trees established
1936	First paper published on predictability of fire behaviour from weather variables
1955	First fire impact study of soil/litter fauna published
1961	First thesis on jarrah and karri silviculture
1964	First thesis on forest floor dynamics and soil properties in jarrah forest
1969	First comprehensive experimental studies of karri silviculture commenced
1970	Commencement of first integrated biological survey
1972	Paper establishing the cause of dieback disease published
1972	Commencement of long term studies of forest mammals - Perup forest
1972	First thesis on forest fire behaviour and fire danger rating system
1972	Commencement of long term study of fire effects in southern forests
1975	Comprehensive review of fire impact studies on flora and vertebrate fauna published
1975	Site-vegetation types in northern jarrah forest described
1980	Hypothesis linking decline of native mammal species to fox predation published
1982	Commencement of long-term study of impact of clearfelling on the karri forest avifauna.
1985	First logging impact study of soil/litter fauna published
1985	First logging impact study of avifauna published
1986	Comprehensive synthesis of knowledge about the ecology of jarrah published
1988	Site-vegetation types in southern jarrah forest described
1989	Comprehensive review of knowledge about dieback disease published
1989	Critical review of fire impact studies published
1989	Publication of multi-authored book on the ecology and management of the northern jarrah forest
1990	Publication of book on threatened flora
1991	Jarrah forest growth inventory completed
1992	Publication of book on the ecology and management of karri forest
1992	Initiation of a four-year study of the impact of spring and autumn planned fire on surface-active species of litter invertebrates
1993	Initiation of multidisciplinary and integrated study of logging and fire impacts in jarrah forest ("Kingston project")
1994	Integrated study of the occurrence of hollows in standing trees commenced
1995	Monitoring commenced of the occurrence of a bio-indicator of large hollows in standing trees (Forest red-tailed black cockatoo)
1995	Comprehensive synthesis of knowledge about the silviculture of karri published
1998	Comprehensive regional assessment published, containing a wealth of new information about forest ecosystems, vegetation complexes, floristic diversity etc.
1999	Planning for an Integrated Forest Monitoring System commenced
1999	Comprehensive synthesis of knowledge about forest avifauna published

ATTACHMENT 2

Table 1: Agreed phased implementation of indicators

Category A—Largely implementable now	Category B—Require some development	Category C—Require longer-term R&D
1.1.a Extent of area by forest type and tenure. (Amended to include 1.1.c) **1.1.b** Area of forest type by growth stage distribution by tenure. (Amended to include 1.1.d) **1.2.a** A list of forest dwelling species. **1.2.b** The status (threatened, rare, vulnerable, endangered, or extinct) of forest dwelling species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment. **2.1.a** Area of forest land and net area of forest land available for timber production. **2.1.d** Annual removal of wood products compared to the sustainable volume. **2.1.f** Area and per cent of plantation established meeting effective stocking one year after planting. **2.1.g** Area and per cent of harvested area of native forest effectively regenerated. **3.1.a** Area and per cent of forest affected by processes or agents that may change ecosystem health and vitality. (A narrative as interim) **4.1.a** (Interim) Area and per cent of forest land systematically assessed for soil erosion hazard, and for which site-varying scientifically-based measures to protect soil and water values are implemented. **6.2.c** Number of visits per annum. **6.5.a** Direct and indirect employment in the forest sector and forest sector employment as a proportion of total employment. (Direct) **7.1** (Narrative) *Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests.* **7.2** (Narrative) *Extent to which the institutional framework supports the conservation and sustainable management of forests.* **7.4** (Narrative) *Capacity to measure and monitor changes in the conservation and sustainable management of forests.* **7.5** (Narrative) *Capacity to conduct and apply research and development aimed at improving forest management and delivery of forest goods and services.*	**1.1.e** Fragmentation of forest types. **5.1.a** Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages. **6.1.a** Value and volume of wood and wood products production, including value added through downstream processing. **6.3.a** Value of investment, including investment in forest growing, forest health and management, planted forests, wood processing, recreation and tourism. **6.4.a(i)** (priority areas) Area and per cent of forest land in defined tenures, management regimes and zonings which are formally managed in a manner which protect Indigenous peoples' cultural, social, religious and spiritual values, including non-consumptive appreciation of country. **6.4.a(ii)** Proportion of places of non-Indigenous cultural values in forests formally managed to protect these values. **6.5.a** Direct and indirect employment in the forest sector and forest sector employment as a proportion of total employment. (Indirect) **6.6.a** Extent to which the management framework maintains and enhances Indigenous values including customary, traditional and native title use by Indigenous peoples and for Indigenous participation in forest management.	**1.2.c** Population levels of representative species from diverse habitats monitored across their range. **1.3.a** Amount of genetic variation within and between populations of representative forest dwelling species. **3.1.a** Area and per cent of forest affected by processes or agents that may change ecosystem health and vitality. **3.1.c** Area and percentage of forest land with diminished or improved biological, physical and chemical components indicative of changes in fundamental ecological processes. **4.1.c** Per cent of stream kilometres in forested catchments in which stream flow and timing has significantly deviated from the historic range of variation. **4.1.d** Area and per cent of forest land with significantly diminished soil organic matter and/or changes in other soil chemical properties. **4.1.d** (Interim) The total quantity of organic carbon in the forest floor (< 25 mm diameter components) and the surface 30 cm of soil. **4.1.e** Area and per cent of forest land with significant compaction or change in soil physical properties resulting from human activities. **4.1.f** Per cent of water bodies in forest areas (e.g. stream kilometres, lake hectares) with significant variance of biological diversity from the historic range of variability. **6.1.b** Value and quantities of production of non-wood forest products. **6.2.b** Number, range and use of recreation/tourism activities available in a given region. **6.5.c(i)** Viability and adaptability to changing social and economic conditions of forest dependent communities. **6.5.c(ii)** Viability and adaptability of forest dependent Indigenous communities.
Total: 12 indicators & 4 sub-criteria	**Total: 8 indicators**	**Total: 13 indicators**

ATTACHMENT 3

EXAMPLES OF POSSIBLE CRITERIA & INDICATORS OF ESFM

LARGE HOLLOWS IN STANDING TREES

Forest red-tail black cockatoo

Coomal (Brushtail possum)

Ngwayir (Western ringtail-possum)

Baudin's Cockatoo

Carnaby's Cockatoo

HOLLOWS IN STANDING TREES

Common brush-tailed phascogale

HOLLOWS ON GROUND

Chuditch

Numbat

OVERSTOREY FEEDER

Spotted pardalote

Striated pardalote

Western white-naped honeyeater

OBLIGATE RIPARIAN SPECIES

Red-winged fairy-wren

Splendid fairy-wren

White-browed scrubwren

Red-eared firetail

SOIL PROPERTIES

Bulk density

Organic C

BATS

FROGS

REPTILES

SLOW TO RECOLONIZE CLEARFELLED KARRI

Rufous tree creeper

White-breasted robin

White-browed babbler

Golden whistler

Western gerygone

Black-faced cuckoo-shrike

INTRODUCED SPECIES OR NATIVE SPECIES NOT ORIGINALLY PRESENT

Red fox

House mouse

Black-shouldered kite

Singing honeyeater

White-fronted chat

Red-capped robin

Willie wagtail

Magpie lark

White-winged triller

Grey butcher bird

Richard's pipit

PLANT SPECIES (S = seed regenerator; R = resprouter; () = first flower 3 or more years after fire)

Acacia pentadenia S (4)

Acidonia microcarpa S

Actinostrobus pyramidalis S (5-10)

Agonis hypericifolia R (3)

Banksia attenuata R

Banksia littoralis S (3)

Banksia quercifolia S (3)

Banksia seminuda S (6)

Banksia verticillata R

Bossiaea aquifolium S

Bossiaea ornata R (3)

Bossiaea linophylla (3)

Conospermum capitatum R (3)

Dasypogon hookeri R

Dryandra bipinnatifida R (3)

Dryandra lindleyana R (4)

Dryandra serra R

Dryandra sessilis S (3)

Dryandra squarrosa

Eucalyptus megarcarpa R/S (4)

Gastrolobium bilobum S (3)

Hakea lasianthoides S

Hakea falcata

Hakea oleifolia S

Hakea trifurcata

Hakea undulata (4)

Hovea trisperma S (4)

Kingia australis R

Lambertia orbifolia

Lambertia rariflora S (6)

Lepidosperma squamatum R (4)

Lomandra integra R (4)

Macrozamia riedei R/S

Melaleuca incana

Melaleuca viminea S (6)

Persoonia elliptica R

Poa homomalla R

Schaerolobium medium R/S

Tetratheca setigera S

Trymalium floribundum S (3)

Trymalium venustum

Xanthorrhoea drummondii R

Xylomelum occidentale R

Xanthorrhoea preissii R/S

LICHEN

MOSS

MYCORRHIZAL FUNGI

Pisolithus tinctorus

Paxillus muelleri

Peziza spp.

Russula clelandii

Amanita xanthocephala

Mesophellia spp.

SAPROTROPHIC FUNGI

Gymnopilus austrosapineus

Coltricia oblectans

Boletellus obscurecoccineus

PATHOGENIC FUNGI

Armillaria luteobubalina

AQUATIC INVERTEBRATES

TERRESTRIAL INVERTEBRATES

Millipedes

*Cynotelopus notabilis (*litter)

Spiders

Storena tetracha (litter)

Dardurus sp.n. (litter)

Baiami spp. (log)

Badumna microps (bark)

Moggridgea tingle (bark)

Chenistonia villosa (bark + soil)

Diaea socialis (foliage)

Sawfly

Tenthredinidae (pupae) (foliage)

Ants

Myrmecia (predator)

Iridomyrmex greensladei (canopy breakdown)

Iridomyrmex anceps JDM 351 (undisturbed forest)

Cardiocondyla nuda (gross disturbance)

Monomorum sp. (post-disturbance)

Papyrus nitidus (undisturbed forest)

ATTACHMENT 4

CALM WORKSHOP

Integrated Forest Monitoring System Concept Plan

7-8 April 1999

Division	Invited	Attended
CALM**Science**	I Abbott	✓
	N Burrows	✓
	S Halse	✓
	G Liddelow	✓
	N Marchant	✓
	J McGrath	✓
	K Morris	N McKenzie
	R Robinson	✓
	A Wayne	X
	M Yung	✓
Management Audit	P Jones	✓
Corporate Services	R Fieldgate	✓
	C Pearce	X
Regional Services	B Chandler	K Williams
	B Harvey	K Low
	P Keppel	X
Forest Resources	P Collins	✓
	J Murch	M Buckton
	M Rayner	✓
	A Seymour	X
Nature Conservation	R Armstrong	✓
	G Wyre	P Orell
Independent	J Bradshaw	✓
	P Christensen	✓

ATTACHMENT 5

CALM Integrated Forest Monitoring System Implementation Group

Ian Abbott (Chair)

John McGrath

Roger Hearn

Graeme Liddelow

Colin Pearce

CALM FORESTCHECK Reference Group

Director of Science Division (Chair)

Director of Sustainable Forest Management

Director of Nature Conservation

ATTACHMENT 6

EXTERNAL WORKSHOP
Integrated Forest Monitoring System Concept Plan
28 October 1999

Institution	Invited	Attended
Murdoch University	Dr Stuart Bradley	X
	Dr Jenny Davis	✓
	Ms Karen Strehlow	✓
	A/Prof Bernie Dell	✓
	A/Prof Ron Wooller	✓
	Dr Mike Calver	✓
Edith Cowan University	Dr Pierre Horwitz	✓
	Prof Harry Recher	✓
Curtin University	Prof Byron Lamont	X
	Prof Jonathan Majer	✓
University of WA	A/Prof Mark Adams	✓
	Prof Don Bradshaw	X
	Dr Dale Roberts	✓
	Dr Andrew Storey	✓
CSIRO	Dr Neale Bougher	✓
	Dr Richard Hobbs	✓
	Dr Robert Lambeck	X
Independent	Dr Mike Bamford	✓
	Dr David Bell	X
	Dr Per Christensen	✓
	Mr Joe Havel	✓
	Dr Barbara Main	✓
	Dr Libby Mattiske	✓
	Dr Owen Nichols	✓
DEP	Mr Colin Murray	✓
Kings Park & Botanic Garden	Dr Steve Hopper	✓
WA Museum	Dr Ric How	✓
	Dr Mark Harvey	X
	Dr Ken Aplin	X
CALM	Mr Alan Walker	X
	Mr Roger Hearn	✓
	Dr Colin Pearce	✓
	Dr Ian Abbott	✓
	Dr Neil Burrows	✓
	Mr Graeme Liddelow	✓
	Dr Neville Marchant	✓
	Dr John McGrath	✓
	Mr Keith Morris	✓
	Mr Matthew Williams	✓

ATTACHMENT 7

EXTERNAL WORKSHOP

Integrated Forest Monitoring System Concept Plan
16 March 2000

Institution	Invited	Attended
Murdoch University	Dr Mike Calver	✓
	Dr Jenny Davis	X
	A/Prof Bernie Dell	X
	Prof I Potter	X
	Ms Karen Strehlow	X
	A/Prof Ron Wooller	X
Edith Cowan University	Dr Pierre Horwitz	X
	Prof Harry Recher*	X
Curtin University	Prof Byron Lamont	X
	Prof Jonathan Majer	✓
University of WA	A/Prof Mark Adams	✓
	Dr Dale Roberts	✓
	Dr Andrew Storey	✓
CSIRO	Dr Neale Bougher	✓
	Dr Richard Hobbs	✓
Independent	Dr Mike Bamford*	X
	Dr Per Christensen	✓
	Mr Joe Havel	✓
	Dr Barbara Main	X
	Dr Libby Mattiske	X
	Dr Owen Nichols	X
DEP	Mr Colin Murray	✓
Kings Park & Botanic Garden	Dr Steve Hopper	X
WA Museum	Dr Ric How	X
	Dr Mark Harvey	X
Water & Rivers Commission	Dr Luke Pen	X
CALM	Dr Ian Abbott	✓
	Dr Neil Burrows	✓
	Dr David Coates	✓
	Dr Janet Farr	✓
	Mr Roger Hearn	✓
	Dr Stuart Halse	✓
	Mr Jim Lane	X
	Mr Joe Kinal	✓

Institution	Invited	Attended
	Mr Graeme Liddelow	✓
	Dr Neville Marchant	✓
	Dr Lachie McCaw*	X
	Dr John McGrath	✓
	Mr Keith Morris	N McKenzie
	Dr Colin Pearce	X
	Dr Richard Robinson	✓
	Dr Bryan Shearer	✓
	Dr Geoff Stoneman	✓
	Mr Bruce Ward	✓
	Mr Adrian Wayne	✓

*provided written comment on draft document

ATTACHMENT 8

TO: All persons who attended one or both of the external workshops

INTEGRATED FOREST MONITORING SYSTEM: CONCEPT PLAN

The draft discussed at the workshop held at Technology Park in March 2000 has now been revised, ready for submission to CALM's Corporate Executive for its consideration.

The October and March workshops provided much valuable advice and assistance in remedying defects in the concept plan. I am also grateful to those who sent in written comment on the document, drawing my attention to mistakes and some unclear portions of the document.

There remain, however, a few suggestions that I am unable to accept. I now list these and provide a brief comment or justification for not accepting this advice. All references are to the draft issued in, and dated, December 1999.

1. Page 7. The sampling design set out was misinterpreted by several participants as being an ANOVA experiment. This was not our intention and the text has been revised.
2. Page 8. Various suggestions were made about changing the plot or quadrat size for sampling plots. The sampling scheme outlined in the concept plan adheres to that operating in the Kingston study. I believe that IFMS should align so far as possible with the detailed research conducted at Kingston.
3. Page 9. It was suggested that a 1 ha plot is too small for sampling jarrah forest birds. This plot size is based on the PhD research of M Craig and is constrained by the 10 ha size of areas cut to gaps. It is important that the census plot has a generous buffer.
4. Page 9. It was suggested that pitfalls for capturing mammals, reptiles and frogs should be filled with glycol and left operative for several months. This is to maximize the sampling of frogs and reptiles, which have episodic pulses in activity related to particular weather conditions. These pulses are unlikely to be detected with sporadic sampling.

   This suggestion has not been adopted because of my concerns that such a procedure of killing all animals pitfalled may compromise future monitoring. I am also concerned about the ethics of killing animals for this purpose.
5. Page 10. Aquatic invertebrates. Advice provided at the March workshop was that there were no suitable indicator species and that an intensive biological survey of streams throughout the jarrah forest was required. This issue has therefore been "parked" on p.7 under section (ix) of the plan submitted to Corporate Executive. I also await with interest the results of the AUSRIVAS research program.
6. Page 11. Statistical interpretation of change. The point raised at both workshops concerning statistical power is accepted. However, it was generally overlooked that with adaptive management there is ongoing collection and analysis of data, so that over time replication will increase. It is thus considered premature to criticize IFMS because of our current inability to estimate power for all but a few taxa.
   In addition, data will also be analysed using ordination techniques for which power considerations are not relevant.

7. Page 14. The graph presented was criticized on the ground that it did not fit one particular data set. However, the text on p.13 made it clear that the graph was a generalized expectation of results and thus was only hypothetical.

Once IFMS is established, my intention is to set up small taxon-based working groups so that interim results can be interpreted by experts in CALM, CSIRO, universities etc.

Thank you for participating in this process. Your input is valued.

Yours sincerely

Dr Neil Burrows
DIRECTOR
CALM**Science** Division

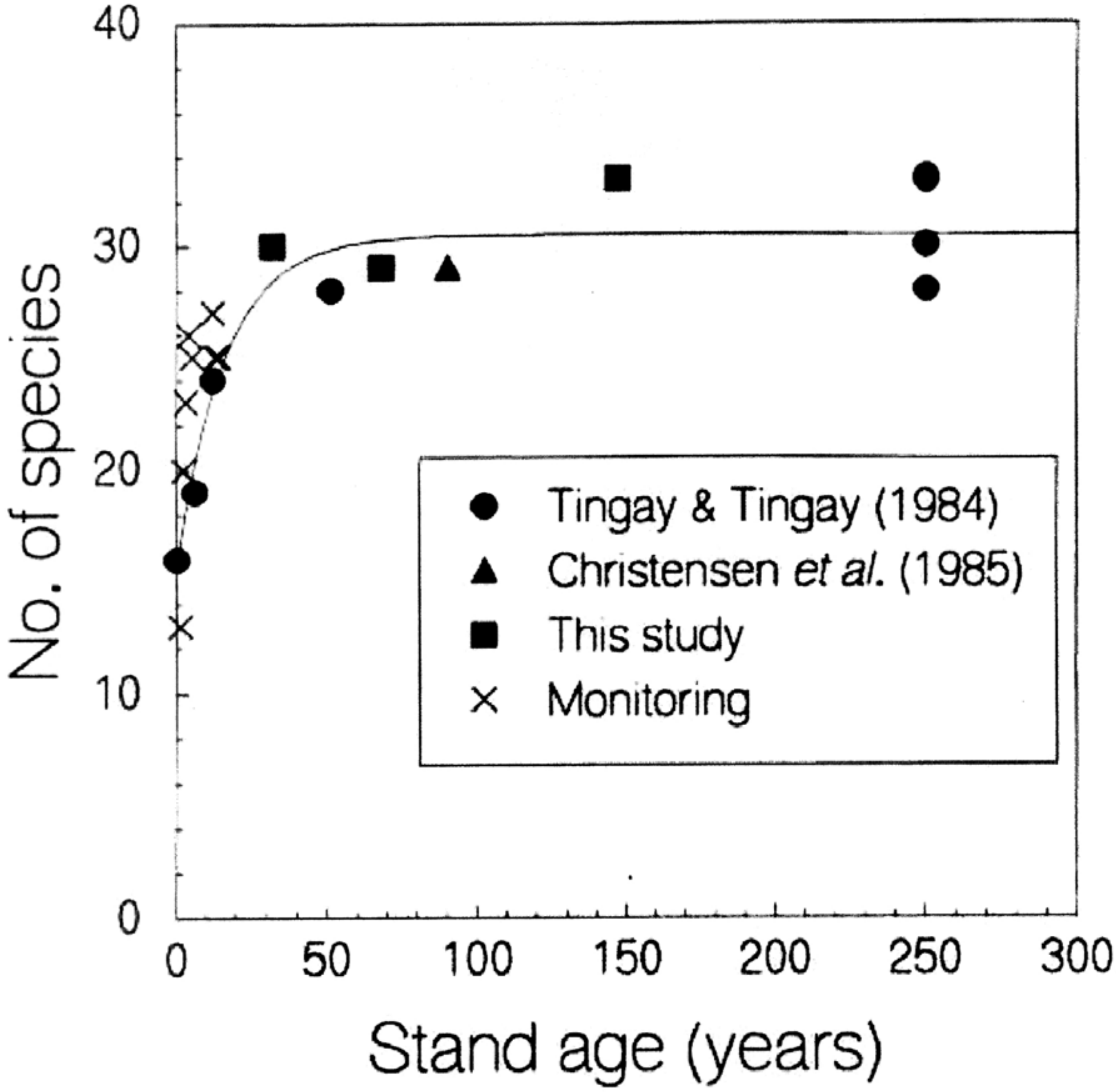
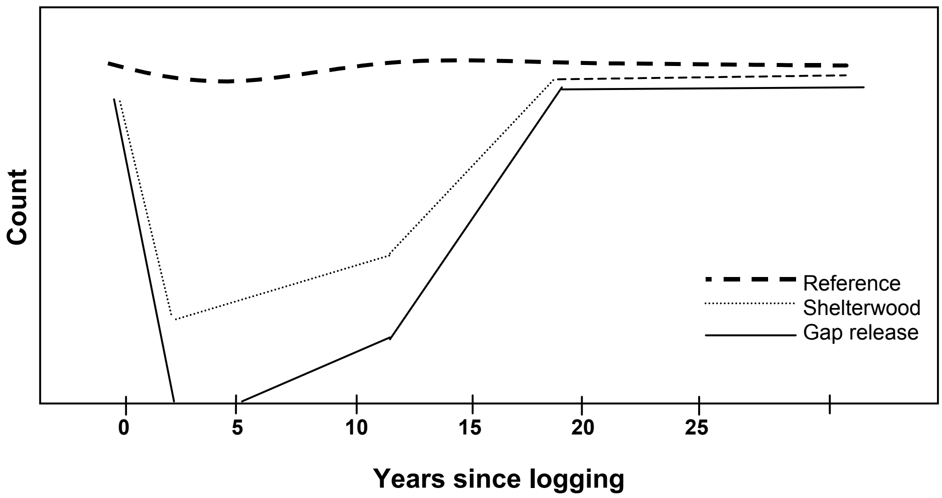

40
30
20
10
0
No. of species
0
50
100
150
200
250
300
Stand age (years)
Tingay & Tingay (1984)
Christensen et al. (1985)
This study
Monitoring

Figure 1

(a)


Count
Reference
Shelterwood
Gap release
0
5
10
15
20
25
Years since logging

(b)

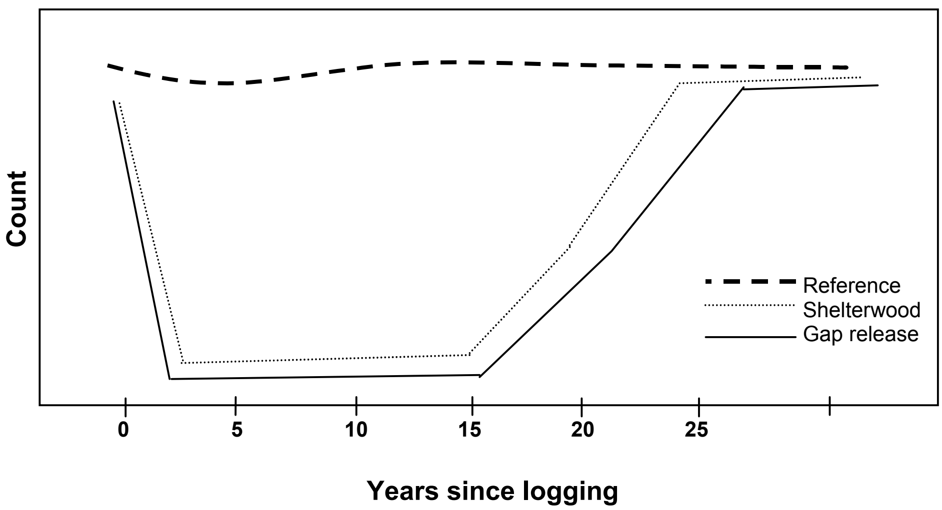
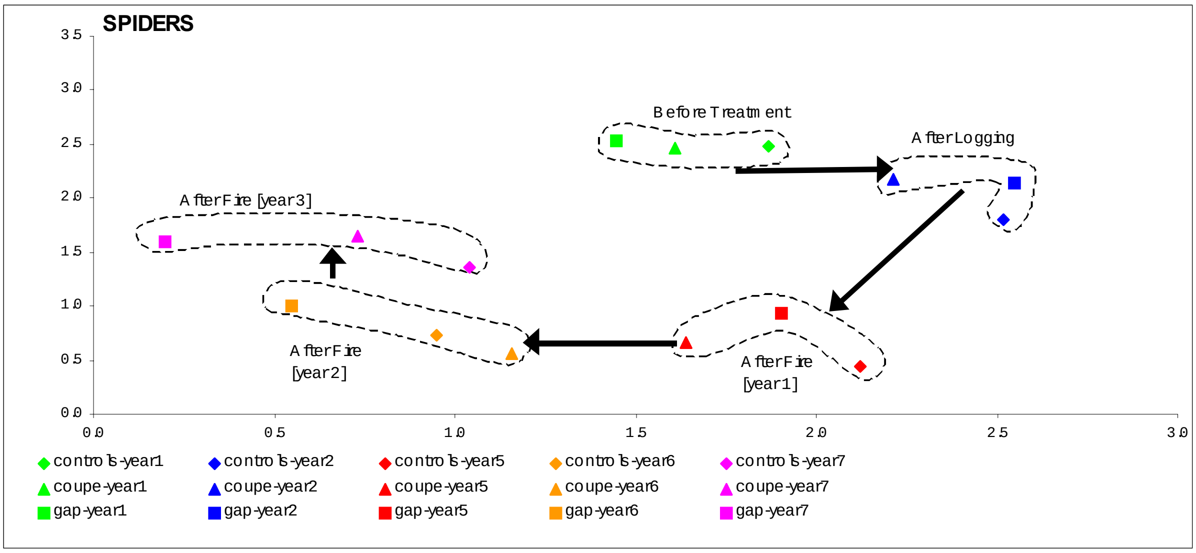

Count
Reference
Shelterwood
Gap release
0
5
10
15
20
25
Years since logging

Figure 2



SPIDERS
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Before Treatment
After Logging
After Fire [year3]
After Fire [year2]
After Fire [year1]
controls-year1
controls-year2
controls-year5
controls-year6
controls-year7
coupe-year1
coupe-year2
coupe-year5
coupe-year6
coupe-year7
gap-year1
gap-year2
gap-year5
gap-year6
gap-year7

Figure 3

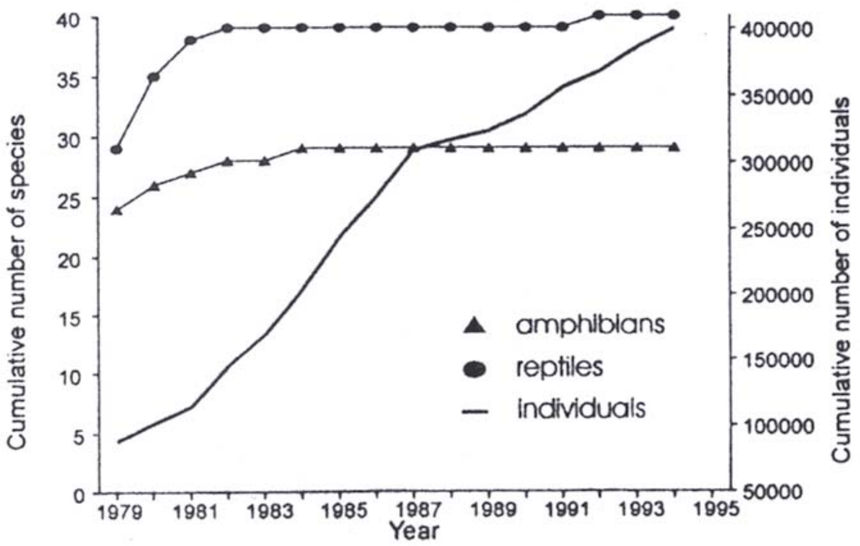


Figure 4. Annual increases in cumulative numbers of species and individual reptiles and amphibians captured at Rainbow Bay. Rainbow Bay is a temporary freshwater wetland habitat (geologically defined as a Carolina bay) and has been completely encircled with a drift fence and pitfall traps since 1978 (18 years).

Figure 4