Developing a framework for the conservation of habitat of RFA priority species – background report 4

A review of approaches used interstate and overseas to monitor the effectiveness of forest management prescriptions for the conservation of biodiversity

***Milestone 19**: Review of approaches to effectiveness monitoring adopted interstate and overseas.*

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Report to the Commonwealth Department of Sustainability, Environment, Water, Population and Communities and the Tasmanian Forest Practices Authority

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FOREST PRACTICES AUTHORITY

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Disclaimers

The information presented is a broad overview of information considered relevant (by the authors) to the brief. Analysis and discussion has been undertaken to different levels of detail but the coverage of material is necessarily incomplete. We apologise for any errors of fact that may have crept into the report and acknowledge that the material presented is based on the opinions and interpretations of the authors.

Front page photograph: The FPA's Biodiversity Program monitors the effectiveness of wildlife habitat clumps at maintaining hollow bearing trees in production forest areas.

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Glossary

Adaptive management: a process of responding positively to change. The term adaptive management is used to describe an approach to managing complex natural systems that builds on common sense and learning from experience, experimenting, monitoring, and adjusting practices based on what was learned.

Biodiversity: the variability among living organisms from all sources (including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part). This includes diversity within species and between species and diversity of ecosystems.

EPBC Act: the *Environment Protection and Biodiversity Conservation Act 1999*, which relates to the protection of the environment and the conservation of biodiversity, and for related purposes.

Habitat: the biophysical medium or media (a) occupied (continuously, periodically or occasionally) by an organism or group of organisms; or (b) once occupied (continuously, periodically or occasionally) by an organism, or group of organisms, and into which organisms of that kind have the potential to be reintroduced.

Habitat tree: a tree that has features of particular value to fauna, frequently including tree hollows. The term 'habitat tree' is often used in reference to trees that are retained on logging coupes for the purpose of providing special habitat for fauna.

LiDAR: LiDAR (Light Detection And Ranging) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses. The range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.

Monitoring: the regular observation and recording of activities taking place in a project or programme.

Monitoring – implementation: monitoring which is used to determine whether prescribed management is actually conducted**.**

Monitoring – effectiveness: monitoring which is used to determine whether the management specified has achieved its objective.

Old-growth forest: ecologically mature forest where the effects of disturbance are now negligible. The definition focuses on forest in which the upper stratum or overstorey is in a late mature to senescent growth stage.

Prescription: a detailed specification of the objectives, area, procedures and standards for a task to be undertaken.

Reserve – formal: one of the following land categories: national park, nature reserve, conservation park, or other legislatively defined reserves for the purpose of conservation.

Reserve – informal: an area set aside for conservation under an approved management plan.

RFA: regional forest agreements (RFAs) are 20-year plans, signed by the Australian and certain state governments, for the conservation and sustainable management of certain areas of Australia's native forests.

Riparian: pertaining to the banks of streams, rivers or lakes.

Snag: a standing dead tree.

Stand: a group of trees or patch of forest that can be distinguished from other groups on the basis of size, age, species composition, condition or other attribute.

Structure: when applied to a forest is the vertical and spatial distribution of the vegetation.

Taxa (taxon): a defined unit (for example, species or genus) in the classification of plants and animals.

Threatened: when used in association with a species, population or community indicates that it is listed under one of the threat categories in the EPBC Act 1999.

Acronyms

AB: Alberta

ABMI: Alberta Biodiversity Monitoring Institute's program

BWMT: Babine Watershed Monitoring Trust

BACI: before, after, control, impact (study design)

BBN: Bayesian Belief Network

BC: British Columbia

CALM (WA): Department of Conservation and Land Management

DEC (WA): Department of Environment and Conservation

DECCW (NSW): NSW Department of Environment, Climate Change and Water

DERM (Qld): Department of Environment and Resource Management

DPI (NSW): Department of Primary Industries

DSE (Vic): Department of Sustainability and Environment

FNSW: Forests New South Wales

FMP: forest management plan

FREP: Forest and Range Evaluation Program

GIS: geographic information system

LiDAR: n Detection And Ranging (LiDAR)

N. CA: Northern California

NGO: Non-government organisation

NSW: New South Wales

NWFP: Northwest Forest Plan

OR: Oregon

PVA: Population Viability Analysis

RFA: regional forest agreement

SLATS: Statewide Landcover and Trees Study

SRD: Sustainable Resource Development

TSC Act: NSW *Threatened Species Conservation Act 1995*

USA/US: United States of America

WFS: Western Forest Strategy

USFS: United States Forest Service

WA: Washington

Contents

Summary

- A program to monitor the effectiveness of management actions for the conservation of biodiversity and to promote adaptive management has been identified as an integral part of any landscape approach to the conservation of forest biodiversity (Bunnell & Dunsworth 2009b; Koch et al. 2011; Lindenmayer & Franklin 2002).
- This report reviews approaches used interstate and overseas to monitor the effectiveness of forest management actions for the conservation of biodiversity. The interstate section reports on the results of a study tour to Victoria, New South Wales, Queensland and Western Australia. The overseas section uses the results of a 2010 study tour to western North America where different approaches have been developed and applied in the past decade. Since this latter study trip is already documented in Munks *et al*., 2010 only a synopsis relevant to this current project will be provided in this report.
- We report on the different approaches, explore the key elements and limiting factors, and make recommendations relevant to a landscape approach to the conservation of forest biodiversity. This document meets, in part, milestone 19 for Part 2 of the project entitled 'Developing a framework for the conservation of habitat of regional forest agreement priority species and a strategic species plan for the swift parrot', being a schedule signed between the Commonwealth and Tasmanian governments dated 2 February 2010 and its variants.

Interstate

- Information on approaches to effectiveness monitoring in other states of Australian was gathered during a 2.5 week study tour to Victoria, New South Wales, Queensland and Western Australia in October 2009 (Koch *et al*., 2011).
- Western Australia was the state found to be most advanced in terms of effectiveness monitoring with a directed and fairly comprehensive program that was used to improve management practices. The WA program includes a small-scale study done on a range of taxa to determine the effect of the forest industry on biodiversity. A larger-scale program has also been implemented to monitor a broad range of taxa in one of the main forest types.
- Victoria and NSW have started to establish large-scale effectiveness monitoring programs. Two broad-scale programs will focus on stand structure and common species of limited taxa to examine overall changes in 'health' of the forest estate. These programs have limited ability to monitor the effectiveness of management actions for individual threatened species.
- While all states visited aspired to following an adaptive management framework, no formal system and processes to achieve this were evident. Management practices appeared to be adapted in an ad hoc and opportunistic fashion and examples were not well documented.

Overseas

- Eighteen different organisations in three different regions of western North America were visited during a study trip in 2010 (see Munks et al. 2010). The information gathered predominantly covered monitoring projects and the associated processes and

programs which were established to evaluate the effectiveness of the policies and management strategies that applied to forest management in each region. The review focused on five main 'management strategy monitoring' approaches:

- The effectiveness monitoring program for the US Forest Service's Northwest Forest Plan (NWFP) which applies to all federal lands in Washington and Oregon, with implications for state-owned and company-owned lands.
- The Forest and Range Evaluation Program (FREP) which aims to determine the effectiveness of the *Forest and Range Practices Act* in maintaining and conserving biodiversity on provincial lands in British Columbia.
- The effectiveness monitoring program for the Western Forest Strategy (WFS), implemented by a private company (Western Forest Products Inc.), which applies to industry-owned and leased lands on Vancouver Island in British Columbia.
- The Babine Watershed Monitoring Trust (BWMT) program which monitors the effectiveness of land-use plans that cover the Babine River drainage, a 400 000 ha region (catchment) in the interior of British Columbia.
- The Alberta Biodiversity Monitoring Institute's program (ABMI) which aims to examine the effectiveness of measures delivered via the Forest Management Planning Standard, and other industry standards, in achieving biodiversity conservation across the landscape – this applies to all land tenures in Alberta.

1. Introduction

Forest management agencies are increasingly recognising the need to measure and report on the effectiveness of forest management strategies for biodiversity conservation and a range of other values. Biodiversity monitoring programs have a fundamental role to play in demonstrating stewardship of the environment and the effectiveness of conservation measures. Many different approaches have been tried around the world but there are few published examples of successful monitoring programs with effective links to management.

Monitoring is a particularly important component of any landscape-scale approach to the conservation of biodiversity in areas outside of the reserve system, where the scientific basis for a particular management goal is unclear and the socio-economic consequences of an over-precautionary approach are high. Monitoring allows decisions to be based less on beliefs and more on facts (McComb, 2009).

There are two main types of monitoring – implementation monitoring and effectiveness monitoring (see Munks *et al.* 2010). Implementation monitoring is used to determine whether prescribed management is actually conducted. Effectiveness monitoring is used to determine whether the management specified has achieved its objective. Both are important in forest management. The need to show that management actions for biodiversity are working and, if not, that management practices are being adapted, is fundamental to the 'social license to operate' increasingly required by forest certification schemes.

This report reviews approaches used interstate (Victoria, New South Wales, Queensland and Western Australia) and overseas (Washington and Oregon USA, British Columbia Canada, Alberta Canada) to monitor the effectiveness of forest management actions for the conservation of biodiversity. We report on the different approaches used in each jurisdiction, explore the key elements of a successful monitoring program and make recommendations

that are considered relevant to a landscape approach to the conservation of forest biodiversity in Tasmania. This report meets, in part, milestone 19 for Part 2 of the project entitled 'Developing a framework for the conservation of habitat of regional forest agreement priority species and a strategic species plan for the swift parrot', being a schedule signed between the Commonwealth and Tasmanian governments dated 2 February 2010 and its variants.

2. Methods

The information provided in this report is the result of both a review of available literature, and information gathered during a two and a half week interstate study trip by AJ Koch in 2009 and a three week study trip by SA Munks in 2010 to North America.

The interstate study trip was conducted between 15 and 30 October 2009 (see Koch et al. 2011) and included Victoria, New South Wales, Queensland and Western Australia where different approaches to the conservation of biodiversity have been, or are being, developed and applied to the forested landscape. Appropriate organisations to visit during this study tour were selected using information available on the internet and in the literature. Existing contacts were also used as a source of information. During the study tour people were interviewed who worked for the industry, for government and for universities (see Koch *et al.*, 2011). Consequently some of the statements made in this report are the results of anonymous feedback and are not supported by published references.

The overseas study trip was conducted between April and May 2010 and gathered information on monitoring the effectiveness of approaches taken to conserve biodiversity in areas subject to production forestry activities in North America. As with the interstate study trip, organisations to visit were selected using the internet, literature and existing sources. During the study tour SA Munks and colleagues visited more than 60 scientists and managers associated with both large-scale and small-scale monitoring programs designed to inform the continual improvement of conservation measures for biodiversity. These programs were in the Pacific Northwest region of the USA (Washington and Oregon) and Canada (British Columbia and Alberta). Much of the relevant information is unpublished, or is hidden in agency reports and guidelines, so the majority of information reported on was gathered during the study tour from the scientists, forest managers and field practitioners visited. Only a synopsis relevant to this current project will be provided in the current report so for full details see Munks *et al*., (2010).

3. Interstate approaches

3.3 Victoria

Approximately 36% of Victoria is forested. Of this approximately 40% is State forest, 45% is in formal reserves and 15% is privately owned. A total of 136 forest-dependent fauna species have been identified as threatened and nine as extinct (Victorian Government 2009). The RFAs identify priority species requiring action statements, with 23 species under the Central Highlands RFA, 40 under the East Gippsland RFA, six under the Gippsland RFA, 23 under the north east RFA, and 17 under the Western RFA. The *Biodiversity strategy* 1997 provides the overarching direction for biodiversity conservation and management in Victoria. The primary legislation relating to biodiversity conservation is the *Flora and Fauna Guarantee Act 1988*. The Department of Sustainability and Environment (DSE) is responsible for implementing this Act, which outlines the broad objectives of conservation management in

Victoria. Within the Act it is stipulated that all listed species/communities require an action statement. A summary of the legislative and policy framework and strategies for conservation of biodiversity in areas outside of reserves in Victoria is provided in Koch *et al.* (2011).

Effectiveness monitoring

We found that historically very little monitoring of the effectiveness of management action for biodiversity conservation has been carried out Victoria, apart from some small-scale directed studies (e.g. Loyn & Kennedy 2009). However, a large-scale monitoring program is currently being established (R Loyn pers. comm.). This program is not designed to assess forest management prescriptions but to provide an overview of changes in forest structure and bird composition. The design of the program is to establish 100 permanent randomly-located sites in each bioregion. Some vegetation communities appear to be under-represented through the current random design, but the final selection of sites is still being negotiated. Each site is to be surveyed every five years. The current design will have more capacity to detect changes in common bird species and is unlikely to detect changes in cryptic and rare species. As yet no thresholds for triggering a management response have been identified.

An additional long-term biodiversity monitoring program, known as Project HawkEye, is being established by DSE to inform the way it conducts planned burning. The project aims to answer key questions about the effects of fire and planned burning on biodiversity. Studies will be conducted in a number of areas, including the Mallee, Otways and foothill forests of Gippsland. The project will build specific partnerships with related projects in these areas. The project was established to address recommendation 58 of the Victorian Bushfires Royal Commission, and will work closely with DSE Land and Fire, Parks Vic and regional staff who are responsible for the planned burning program.

As an additional monitoring tool, Bayesian Belief Networks (BBNs) are being developed for individual populations of threatened species. The BBNs model the causal relationships between management actions, threats and population/habitat parameters to assist in evaluating management options. Summary data on population status and threat severity can be aggregated across populations for reporting purposes. The BBNs are constructed within an information system (the Actions for Biodiversity Conservation system) which ensures integration between the planning, reporting and modelling functions. The models can be used to direct monitoring effort, potentially broadening the range of factors considered rather than simply focusing on the size or density of the population itself. By collecting data on the severity of threats and the status of population/habitat parameters, the BBN models can be progressively refined, which will improve ecological understanding and contribute to adaptive management.

Adaptive management

It is stated that action statements be reviewed and updated every three to five years, but in practice this is done only infrequently. The *Code of practice for timber production* (Department for Sustainability and Environment, 2007) was reviewed in 2006 when it became more outcome-based. Management procedures for timber harvesting in Victoria's State forest are reviewed annually by DSE and then put out for consultation. While some minor changes have been made through these reviews, only limited changes to the harvesting procedures has occurred. Major changes require negotiation with VicForests. The zoning in East Gippsland is currently being reviewed to try and maintain the level of retention but use on-ground information and PI-type data to reassess the distribution of retained areas.

3.4 New South Wales

New South Wales has a diverse forested landscape, with around 215 unique forest types, at least 150 of which are used by the forest industry (R Kavanagh, pers. comm.). There are a large number of threatened plant and animal species in NSW (http://www.threatenedspecies.environment.nsw.gov.au), with 26 priority species listed in the Eden RFA, 157 in the northeast RFA and 121 in the southern RFA. The government organisation legally responsible for biodiversity in NSW and for administering the *NSW Threatened Species Conservation Act 1995* (TSC Act) is the Department of Environment, Climate Change and Water. Forests New South Wales (FNSW) is responsible for managing 2.5 million ha of publicly-owned forest lands for timber and wildlife in accordance with the complex legislative and policy framework, including the regional forest agreements. For a more detailed account of the legislative and policy framework and strategies for conservation of biodiversity in areas outside of reserves in NSW see Koch *et al.* (2011).

Effectiveness monitoring

A large number of small-scale studies have been done assessing the effectiveness of particular management strategies (e.g. Kavanagh et al. 1995), but only minimal effectiveness monitoring at the regional scale has occurred. However, a large-scale effectiveness monitoring program is currently being established by FNSW in NSW forest areas (R Kavanagh, pers. comm.). Sampling plots will be established according to a grid-based system for an unbiased design. Two pilot studies have been done to establish the sampling strategy, which will involve monitoring plants, birds and bats, while other fauna groups are currently under consideration. The frequency of sampling has yet to be established but will involve multiple visits to a site within one year, but not necessarily sampling each site every year. The design means the program will focus more on common species, with limited ability to monitor many threatened species. Targeted research programs will need to be conducted for less-common species. While high-order objectives have been set, finer-scale targets and objectives for the monitoring program have yet to be established. This is at least partly because the scientists do not believe they have sufficient knowledge to set targets for most species. Natural variability in species occurrences or population sizes is so poorly understood (especially given the severe drought over most of the past decade) that the decision was made to begin the regional-scale monitoring program now and to learn as it progresses. When established, the targets will be based on occupancy rather than population size for most species. If thresholds of concern are met, the intent is that this will trigger a targeted research program for the species of concern.

Forest structure and condition are currently being monitored by field assessment of permanent plots. Research is underway to determine whether it is possible to use remote-sensing technologies to provide indices for forest structure and condition and eventually to serve as surrogates for the habitat of many species.

Adaptive management

While there are procedures in place to review relevant documents, only minimal adaptive management occurs in NSW. The potential for true adaptive management is hindered to some extent by the structure of the management system (i.e. using species records to dictate management). The pre-harvest surveys provide only presence data (no absence data) and there are no repeat surveys, meaning there is limited capacity to improve understanding of the ecological requirements of species and thereby improve management practices. The lack of clear objectives and the prescriptive approach adopted in NSW also inhibits adaptive management.

3.5 Queensland

About 30% of Queensland is covered in native forest (ABARES 2011), with around 80% of forests publicly owned (much of it as leasehold land) and at least 13.6% of public forests used for the commercial production of forest products (www.AustralianForests.org.au). The *Forestry Act 1959* deals with the management of State forests and the use of forest products on other crown lands. The *Environmental Protection Act 1994* aims to protect the environment while allowing for development in a way that maintains ecological processes. The Queensland codes of practice provide guidance for forest practices, with compliance to the public code of practice (*Code of practice for native forest timber production on state lands*) required under the *Vegetation Management Act 1999*, but the private code being unlegislated.

Effectiveness monitoring

The Statewide Landcover and Trees Study (SLATS) is a procedure that has been developed to monitor land clearance. The process uses satellite image data and GIS techniques combined with field verification to detect changes in land cover and vegetation composition. In relation to the forest industry, the Department of Environment and Resource Management (DERM) is in the process of reviewing compliance to the code of practice that applies to freehold land. Some small targeted studies have been done relating to the effectiveness of management practices (e.g. Eyre et al. 2009; McAlpine et al. 2006), but there is no monitoring of species and only minimal monitoring of habitat structure.

Adaptive management

The Queensland code of practice that applies to timber production on State land is reviewed every five years, although the Minister has the capacity to make changes to it at any time. In practice any adaptive management that occurs is largely opportunistic and driven by individual interest. Furthermore, there is limited capacity to significantly change prescriptions in the code due to the timber agreements made with the industry. A 25-year wood supply agreement, ending 31 December 2024, was signed after the South East Queensland Forests Agreement 1999 reduced the area available for harvest.

3.6 Western Australia

About 9% of Western Australia is forested. Areas of value to the timber industry are located only in the south-west corner of the state and comprise only 10% of the forested land. The south-west of Western Australia has been identified as one of 25 global biodiversity 'hotspots' due to the high number of endemic plant and animal species in the region. Despite this, the diversity of forest types used for timber production and the number of threatened forest-dependent species is lower than for most other mainland states of Australia. The majority of the forested land managed for timber production is publicly owned. The legislative framework includes the *Forest Products Act 2000* and *Conservation and Land Management Amendment Act 2000.* The Forest Management Plan (FMP) is the main document governing forest management.

Effectiveness monitoring

Western Australia is the Australian state that is most advanced in terms of monitoring the effectiveness of forest management for maintaining biodiversity. In 1993 a small-scale but detailed series of studies (collectively called the 'Kingston Study') was initiated to examine the direct impact of partial harvesting on select plant and animal species in jarrah forest. While many other states have conducted similar studies (e.g. the impact of harvesting on

avifauna), none are as comprehensive in number of taxa examined. Around 2001, the Kingston Study (which was intensive, and examined immediate impacts at a small spatial scale) led into the complementary FORESTCHECK program (which was broader in spatial and temporal scale and scope). Compared to monitoring programs being established in Victoria and NSW, the FORESTCHECK program is very detailed and monitors a large range of taxa. In addition to the broader monitoring programs, some studies have also been done to assess the effectiveness of forest management for maintaining particular species (e.g. Abbott 1998). The burning regime in Western Australia is one of the best examples where a clear science-based target has been established that facilitates monitoring and adaptive management (Burrows 2008).

The history of close ties between industry and management bodies in Western Australia (as well as public pressure) is probably one of the reasons for the relatively early establishment of monitoring programs and level of adaptive management that has occurred. For the strategies and taxa that have not been monitored or assessed, it is assumed that the measures in place at the landscape scale are adequate for their conservation.

Kingston Study

Around 1993, a number of integrated studies, known collectively as the Kingston Study, were initiated to assess the impact of partial harvesting on selected groups of plants and animals in the jarrah forest (Burrows et al. 1994). Much of these studies employed a replicated BACI design (before, after, control, impact). The harvesting techniques examined were shelterwood and gap-logging with and without retained habitat trees. Unharvested areas were used as control sites. The Kingston Study was relatively comprehensive in scope, examining forest structure, vascular plants, avifauna, ground-dwelling and arboreal fauna and invertebrates (Abbott et al. 2003; Burrows et al. 2002; Morris et al. 2000; Morris et al. 1996; Strehlow et al. 2002; Wayne et al. 2001). The project was limited in spatial scale and replication (n = 24), with the scale of the study being more appropriate for some taxa than others (Craig & Roberts 2005).

With CALM being one of the key stakeholders in the Kingston Study, there seems to have been excellent communication between research and management, with a focus on applied, practical results. For example, one report (Wayne et al. 2000) discussed issues with current management and recommendations to improve forest management. These recommendations included the need for clear goals and objectives and the need to increase survivorship of animals during harvesting. Secondary effects of harvesting were also identified, with predation shown to be a major source of mortality for some fauna (Wayne *et al.* 2000). The results of the study have been used to review some management practices, such as the rate of habitat tree retention, implementation of fauna habitat zones, retention of other forest attributes, reduction in soil disturbance, increased predator control associated with harvesting, modified burn practices etc. The Kingston Study has also been a key part of the development of the FORESTCHECK program.

FORESTCHECK

The FORESTCHECK program aims to monitor the changes and trends in key elements of forest biodiversity associated with a variety of forest management activities (Abbott & Le Maitre 2010). The current focus of the program is on timber harvesting and fire in the jarrah forests, although the intent is to extend the program and examine other disturbances and forest types. Each of five ecological regions has 10 grids that are 2 ha in size. The sites selected were stratified by ecological gradients (rainfall, fertility) and future harvesting. Within each plot assessments are done on the following: forest structure, soil and leaf

nutrients, soil disturbance, coarse woody debris and litter, fungi, cryptogams, flora, invertebrates and vertebrates. This program is in the early stages and a five year synthesis is currently being compiled. It is expected that the results of this synthesis will inform the next Forest Management Plan. Current results indicate that the main group of concern is the cryptograms (I Abbott, pers. comm.). The program has also highlighted coarse woody debris as an issue of concern.

Adaptive management

There is a strong history of research leading to strategic landscape-scale management of the forest estate in Western Australia. The high level of uptake of research is possibly a result of the close association between research and industry bodies. In Western Australia there is a clear administrative pathway for responding to increasing knowledge of forest management, but there are no triggers to initiate this process. Western Australia seems to be fairly good at passive adaptive management.

An example of the adaptive management process is seen in the evolution of forest structural goals. The principal purpose of whole-of-forest goals is to provide assurance that the oldest development stages are adequately represented, that regeneration is occurring at a satisfactory level, and that there is a reasonable degree of stability over time. The karri forest structural goals in the 1994 Forest Management Plan were based on a simplified model of mortality and regeneration at the rate of 0.5% per annum up to 200 years. It was acknowledged that having only mature forest in reserve may affect long-term forest dynamics. In 2002 a consultant was commissioned to review the forest structural goals (Bradshaw 2002). The revised goals aim to specify the proportion of the forest that should be maintained in each age class so that as older trees die they are replaced by successively younger trees. The age distribution of very fire sensitive species tends to follow a negative exponential form; moderately sensitive species that may be both even-aged and uneven aged tend towards a 'normal' distribution skewed to the left, and that of fire tolerant species more skewed to the right. This distribution is now used to guide burn regimes in Western Australian forests (Burrows 2008).

The Forest Management Plan expires after 10 years, and there is a mid-term audit of performance. There is minimal capacity to edit the Forest Management Plan between the five yearly revisions, largely due to the bureaucratic process required to change documents (i.e. public consultation and ministerial approval). This prevents even minimal changes being made that may improve clarity without changing intent or strategy. For example, there is a desire by the Department of Environment and Conservation (pers. comm.) to clarify that recruitment habitat trees should be co-dominant trees, not young trees, but this amendment has not been changed due to the process. The management recommendations delivered by internal documents (e.g. sustainable forest management guidelines) are more likely to be updated as new information becomes available.

3.7 General observations

One general observation made during this review of interstate approaches was that there needs to be more monitoring to evaluate whether or not what we have done has been effective in achieving our goal or objective. We were told that in some areas it is assumed that things are being managed adequately as a result of the RFA review. However, it seems that all states have done some research to help improve biodiversity management in production forests. One researcher reported that science is frequently targeted to those species that cost the industry the most (e.g. nocturnal species).

Western Australia conducted a relatively small-scale but intensive study that was targeted to assessing the impact of harvesting practices on biodiversity (the Kingston Study). The results of this program have been used to improve management. Victoria, NSW and Western Australia are currently developing broad-scale effectiveness monitoring programs. These programs differ in the design of sampling plots, intensity of survey and in the entities being surveyed. When we spoke to people it seemed that objectives were rarely articulated explicitly. Mostly these programs will have greater capacity to detect change in common species or habitat structure rather than rare species. Victoria and NSW have greater spatial replication, while the diversity of entities being monitored is highest in Western Australia.

Of interest was the alternative approach for monitoring being explored in Victoria – establishing population models to use as a baseline for monitoring programs. The increasing reliance on remote sensing was also interesting. Aerial photograph interpretation has been heavily used in most states. LiDAR is being explored in some states (e.g. NSW), but the costs involved are prohibitive for many areas or extensive use. Queensland uses satellite imagery to monitor land clearance. Practitioners stated that there were issues with maintaining up-to-date mapping layers and information available does not always meet the requirements for management.

4. Overseas approaches

Eighteen different organisations in three different regions in western North America were visited during a study trip in 2010 (see Munks *et al*., 2010). The information gathered predominantly covered examples of monitoring projects and the associated processes and programs which were established to evaluate the effectiveness of the policies and management strategies that applied to forest management in each region.

4.1 Washington and Oregon, USA – monitoring the Northwest Forest Plan

The two north-western states of USA (Pacific North-west) support extensive forests, and forest industries have contributed substantially to their local economies. In response to public concern about forest management in the region and its impact on threatened species, a plan– the North West Forest Plan (NWFP) – was developed by a group of academics and bureaucrats and accepted by Congress in 1994. The plan applies to all national and state forests within the range of the northern spotted owl in USA, hence including all the public forests in western Washington, western Oregon and parts of north-western California (9.9 million hectares). It involved a radical reduction in the extent of logging in national forest, a move away from clearfelling and the introduction of comprehensive prescriptions for conserving selected threatened species on those lands.

Effectiveness monitoring

Monitoring of the NWFP is targeted predominantly at evaluating whether or not the strategies delivered by the plan are effective at maintaining populations of the key focal species, spotted owl and marbled murrelet (Lint et al. 1999; Mulder et al. 1999). Species surveys and different types of modelling (demographic, PVA and limited habitat modelling) have been applied to help predict management outcomes. Monitoring of both these main target vertebrates of the NWFP has shown a decline in the species in recent years. The decline in the spotted owl was initially thought to be due to continuing deterioration of habitat. However, an expansion in the range of the barred owl, picked up during surveys by amateurs, is now thought to be a prime reason. A more broadly based monitoring program might have

detected this issue at an earlier stage. Monitoring of marbled murrelets, however, does give data on multiple species thus helping distinguish effects of forest management (affecting only marbled murrelets) from the multitude of other variables that affect the marine environment. [Note, marbled murrelets are seabirds that depend on oldgrowth forest for breeding].

There is no regular monitoring of other elements of the biota, in relation to forest management. Some national monitoring of songbirds is organised by NGOs (Audubon Society, etc) but this work is not designed to inform forest management, and we did not become aware of any systematic attempt to interpret the data in relation to forest management.

Old-growth forest monitoring is mainly done by remote sensing, but this links with a plot-based monitoring project run and funded separately by the US Forest Service. It uses Landsat imagery (now freely available to the public). The monitoring shows that 30–35% of forests in the Pacific Northwest can be considered to be in old condition, compared with ~60% before European settlement. However the Remote Sensing Change Detection Project shows that the age structure of the forest in the NWFP area is increasing as less harvesting is done (M Moeur pers. comm.). Broad-scale and extensive monitoring of aquatic systems is also being carried out by scientists in the US Forest Service. The objectives of this catchment monitoring program are to assess the status and trend in condition of headwater systems and to monitor the effectiveness of land management plans in maintaining and restoring catchment condition (S Lanigan pers. comm.). This involves sampling 250 randomly selected catchments with 25 sampled per year on a 10-year rotation. Sample sites are on federal lands and LiDAR is being used to locate streams.

Adaptive management

The concept of adaptive management was developed largely in North America (Bunnell & Dunsworth 2009a; Walters & Holling 1990). However, few formal examples were encountered during the study trip (Munks *et al.,* 2010). The main issue identified by Munks *et al*. (2010) was that the collection of forest monitoring programs was too narrowly focussed on only a few species. They tentatively concluded that the main barrier to a culture of adaptive management in this region stems from the lack of a broad-based program to evaluate the effectiveness of management strategies on flora and fauna, including those groups of most interest to the community.

4.2 British Columbia, Canada

British Columbia is approximately 95 million hectares in size. As such it is similar in size to the Australian state of New South Wales (80 million ha), but is significantly larger than Victoria and Tasmania combined (30 million ha). About two-thirds of the province (59 million hectares) is forested (Ministry of Forests and Range 2006) and the majority is of importance to the timber industry. One major effect of logging in the province is a shift from the predominance of older forests to a landscape dominated by younger forest (Pojar & McKinnon 2004). Despite the changes resulting from human land-use activities, British Columbia is one of the few regions in the world where there are examples of large intact areas of forest in which the native biodiversity remains similar to that which occurred before European colonisation (Pojar & McKinnon 2004).

Forest management practices are regulated by the *Forest and Range Practices Act 2005*. The forest practices system is result-based with minimum standards being prescribed. A series of objectives or desired outcomes are listed in the regulations of the current Forest and Range Practices Act and professionals (foresters and forest managers) are relied upon to develop

ways to meet these desired outcomes. The other key piece of legislation that, along with the Forest and Range Practices Act, guides the approach to conserving biodiversity in the forests of British Columbia is the *Land Act 1996*. The Land Act has regulations that legalise aspects of high-level land-use plans for different regions (e.g. Vancouver Island Land Use Plan, Coastal British Columbia Land Use Plan, Bulkley Land and Resource Management Plan, Interagency Planning Team 1998). These plans integrate a range of land-use activities, including forestry.

Effectiveness monitoring

Although there is no requirement for monitoring under the Forest and Range Practices Act, a lot of resources are allocated to monitoring the effectiveness of forest management strategies in British Columbia. Munks *et al.* (2010) observed that this was probably a result of market-based requirements. That is, the need to demonstrate a commitment to forest stewardship (social licence to operate) and continual improvement (certification requirement).

The Forest and Range Evaluation Program (FREP) is a major multi-agency initiative which aims to determine the effectiveness of the Forest and Range Practices Act in maintaining and conserving biodiversity on provincial lands in British Columbia. The FREP program defines monitoring as *'the act of conducting multiple surveys over time or across areas to examine an object or activity in order to document its condition',* and evaluation as *'the act of ensuring progress toward stated objectives'* (Paige & Darling 2009). The effectiveness evaluations planned under the program incorporate trend monitoring (baseline or status) and implementation monitoring. Research projects to gather knowledge and to validate basic assumptions are also carried out under the program to complement the effectiveness monitoring (Paige & Darling 2009). The program recognises that flexibility in the type of monitoring is needed to deal with the inherent complexity of monitoring wildlife and the variety of biodiversity management practices to be evaluated.

The first phase in the FREP program is to develop measurable objectives and questions for the eleven key environmental values covered by the Act. Determination of FREP priorities for monitoring are based upon the perceived level of risk. Species and ecosystems are also ranked based on a number of criteria including their conservation priority and the importance of the practice to the species' overall conservation (Paige & Darling 2009). The second phase is the identification of appropriate indicators and thresholds to address the monitoring questions. The third phase in the FREP program involves project design and implementation – development of protocols, pilot projects, collection and analysis of data. The final phase includes evaluation and reporting of results and recommendations to the forest managers (Snetsinger 2009). A considerable amount of resources are expended on communication of the results of the program through extension notes (e.g. Bradford & Smith 2009), a toolbox for forest managers, articles in newsletters and 'continuous improvement' meetings with industry.

An example of a more targeted effectiveness monitoring program observed by Munks *et al.* (2010) is the Western Forest Strategy (WFS), implemented by a private company (Western Forest Products Inc.) and applying to industry-owned and leased lands on Vancouver Island in British Columbia. The project monitors a number of indicators relevant to the goals of the Western Forest Strategy. The program uses a multi-species approach. Forest-dwelling species, selected based on their sensitivity to forest practices, ease of monitoring, and utility of information to guide management, are also monitored (Bunnell & Dunsworth 2009a)(Kremsater *et al.*, 2003; Beese *et al*. 2005; Beese and Deal, 2009). Ecosystem representation monitoring uses the biogeoclimatic ecosystem classification developed for

British Columbia. Habitat surrogates are used where the relationship between a species and a particular habitat type or element have been established. For example, assessments are done on the amount and characteristics of stand structural elements, such as snags, that are retained after harvest. Habitat monitoring is carried out at both the landscape- and stand-scale. At the landscape-scale there is some use of mapping and inventories based on remote-sensing, although permanent ground based transects are also used.

The Babine Watershed Monitoring Trust (BWMT) program is another example of a targeted program monitoring the effectiveness of land-use plans that cover the Babine River drainage, a 400 000 ha region (catchment) in the interior of British Columbia (Munks et al. 2010). This program was set up to resolve conflicting views on the effects of catchment management plans on the environment. The trust was chosen as the only governance structure that would allow diverse and conflicting interests to participate in monitoring the land-use plans, such that no single interest could control the results. The trust identifies the actions found to be most likely to meet the plan objectives, and then initiates projects to evaluate the effectiveness of the actions. This approach avoids wasting valuable resources on projects that are not going to deliver useful results for management. Projects selected for funding use a variety of methods, including retrospective studies.

Adaptive management

Munks *et al.* (2010) found that the FREP has a clear process by which the outcomes of projects are reported (Paige & Darling 2009; Snetsinger 2009), but that the process by which decisions are made to adapt management was unclear.

The WFS, initiated by the private company MacMillan Bloedel, includes a clear process for feedback to management to enable revision of the strategy based on results of monitoring and research (Beese and Deal, 2009).

The Babine Watershed Monitoring Trust makes recommendations about updating existing land-use plan objectives and strategies to a community resource board which includes representatives from the provincial government. This board then makes the decision on what needs to be changed in the land-use plan. Munks *et al.* (2010) observe that the success of this process depends very much on champions within government and industry – people who support innovation and change.

4.3 Alberta, Canada – monitoring the *Forest Management Planning Standard*

Alberta covers more than 66 million ha (approximately 80% of the area of New South Wales), 58% (38 million ha) of which is forested. Of the forested area, about 60% (22.5 million ha) is available for commercial harvest (approximately 35% of Alberta's total area) (Munks et al. 2010). The Alberta Department of Sustainable Resource Development (SRD) is responsible for managing forestry operations in the province and this is achieved primarily through a range of forest tenure agreements with private industry. Forest management plans (FMPs) are the most common forestry tenure arrangements in Alberta. The Alberta *Forest Management Planning Standard* provides the guidelines for preparing FMPs, including values and objectives, and sets the minimum performance standards expected in terms of indicators and targets.

Effectiveness monitoring

The *Forest Management Planning Standard* provides guidance on targets to meet the minimum performance standards for forest management. Munks *et al.* (2010) note that companies do their own monitoring to determine whether targets are achieved for each objective (implementation monitoring). However, this monitoring does not indicate whether the targets and actions delivered by the forest management plans are meeting the objectives for biodiversity conservation (effectiveness monitoring). This is the aim of the Alberta Biodiversity Monitoring Institute's program (ABMI). The ABMI program attempts to examine the effectiveness of targets and actions delivered via the *Forest Management Planning Standard*, and other industry standards, in achieving biodiversity conservation across the landscape – this applies to all land tenures in Alberta. Forest companies and resource extraction industries in Alberta contribute funding (>20%) for biodiversity monitoring by the institute. Government support for ABMI demonstrates its belief that the program provides the best opportunity to examine the effectiveness of company forest practice standards in achieving biodiversity conservation, while industry support is based on the capacity of the program to provide the information requirements for reporting to maintain certification.

The program was initiated in 1997 and involves regular and systematic sampling of a wide range of land, water and living resources across the province. It monitors changes in habitat quality, ecosystem integrity and the occurrences of a large number of species across all land tenures in Alberta. The program became fully operational with improved methodology and standards in 2007. It generates value-neutral, independent, publicly-accessible data, including comprehensive indicators and reference points, to inform government, industry and the public about the state of the environment. The five-yearly re-sampling schedule for each site will provide an important measure of the cumulative impacts of natural resource policies, including those specific to forestry.

The primary aim of the program is to identify trends in species and their habitats before they become threatened. While not designed specifically to collect data on rare species, the ABMI program does provide useful information for monitoring the status of some conspicuous threatened species (e.g. grizzly bear; data required by the Alberta Fish and Wildlife Division of SRD). Also, the systematic data collected by the program provides excellent support for proposed listing or de-listing of threatened species.

Adaptive management

Munks *et al.* (2010) did not find any clear examples of adaptive management as a result of the monitoring program. However, the species-habitat associations detected by the ABMI program serve to generate hypotheses that can be tested by scientific research and thus contribute to improved management objectives and target setting within the natural resource management cycle. This linkage between monitoring and research is an effective way of focusing limited research resources to answer questions of real significance to biodiversity conservation. Together, the Alberta *Forest Management Planning Standard* and the Alberta Biodiversity Monitoring Program should lead to significant improvements in the development of integrated landscape management plans and contribute to progress in achieving the goal of biodiversity conservation in the forests of the province. However, Munks *et al.* (2010) note that a concurrent and more targeted operational-scale research program would be required to fast-track the evaluation of any new management alternatives.

4.4 General observations

The overall monitoring effort for the Northwest Forest Plan has two major limitations, which may have had adverse effects on the ability of forest managers to respond adaptively. Firstly, it has focused excessively on the target threatened species, with the result that little is known about how other forest species are faring, including common species that may provide early warning of changes in ecological processes that may need to be managed. Secondly, it has not included targeted research and monitoring to evaluate the effectiveness of any changes to management actions, such as retaining habitat within harvested areas (at least not in a systematic way). We believe these limitations could be easily overcome, and should be avoided in any program designed for the Tasmanian forest practices system.

The monitoring context in British Columbia is a complex legislative and policy environment with a plethora of competing objectives and indicators. One weakness of the current approach identified by the British Columbia Forest Practices Board is the fact that some of the objectives in regulations do not say what they intend to achieve. There are some (e.g. for wildlife tree retention and coarse woody debris) but in general it is up to the licensee to propose measurable results or strategies in their forest stewardship plans that are consistent with established objectives for stand- and landscape-level biodiversity conservation in the regulations. This means that resource managers are often not sure what they are trying to achieve. This has also caused problems when trying to monitor compliance or effectiveness of actions via the Forest and Range Evaluation Program. This highlights the need for clear and measurable targets/objectives.

Alberta was the only jurisdiction visited during the study trip by Munks *et al.* (2010) that had a comprehensive and integrated program of forest management for biodiversity. The Alberta Biodiversity Monitoring Institute's program (ABMI) operated at the landscape-scale and was supported by both government and all industries involved in natural resource exploitation and use. The establishment of values, objectives, indicators and targets for forest management (in the *Forest Management Planning Standard* and ground rules), combined with a state-of-the-art monitoring program for biodiversity, has produced a powerful natural resource management approach that has gained widespread public support and confidence. The ABMI program operates mainly at the landscape-scale (an aggregation of stand-level responses), but is currently investigating opportunities to increase monitoring resolution to the site-scale using remote-sensing. In this way, the ABMI grid-based trend monitoring approach has the potential to develop into a comprehensive effectiveness monitoring program. It also has the capacity to monitor the cumulative effects of natural resource management on biodiversity and habitat elements at the landscape, and potentially, site-scale. In the meantime, there may be a need for the ABMI program to be accompanied by an operational-scale research and monitoring program to investigate the effectiveness of certain management activities delivered via the *Forest Management Planning Standard* and ground rules for conserving biodiversity.

Table 1 Summary of features of the monitoring programs learnt about in this review (adapted from Munks et al. 2010)

Monitoring program (organisation)	**Drivers**	**Scale**	**Type of monitoring***	**Feedback to management**	**Summary of strengths and weaknesses**
Victoria	Forests Act	Public forests state-wide	Area occupancy by birds Vegetation health and structure	Uncertain as program yet to be fully established	Broadscale, intensive sampling to detect broad trends. Limited power to monitor rare species Monitor only small range of taxa Not designed to answer specific management question Expensive
NSW - FNSW	Economic consideration (reduce pre-harvest surveys)	State forests state-wide	Area occupancy by plants, birds and bats Vegetation health and structure	Uncertain as program yet to be fully established	Broadscale, intensive sampling to detect broad trends. Little power to monitor rare species Not designed to answer specific management question Expensive
Queensland	Land clearance legislation	State-wide	Change in landcover	Unknown	No regional study on the effect of management on biodiversity, so no true effectiveness monitoring.
WA – Kingston Study	Forest Management Plan	Kingston Forest Block	Impact of partial harvesting systems on a range of taxa	Good communication and results appear to have informed management changes and further monitoring	Monitor wide range of species Limited replication
WA – FOREST CHECK	Forest Management Plan	Donnelly District	Impact of two major types of logging on forest biodiversity in dry schlerophyll jarrah and	Good communication	Monitor wide range of species rather than relying on surrogates Monitor forest structure, foliar and soil nutrients and soil disturbance.

			marri forests		Limited to one forest type Not a regional assessment
Northwest Forest Plan monitoring program (NWFP) (US Forest Service)	Northwest Forest Plan (legal directive)	All US National Forests in WA, OR and N. CA	Trend, effectiveness and validation Vegetation cover, extent and condition Watershed and riparian condition Threatened species 'Survey & manage'	Good communication but no direct feedback	Legislative requirement Predominantly based on habitat surrogates and short list of iconic threatened species No systematic evaluation of the effectiveness of new management techniques Expensive
Forest and Range Evaluation Program (FREP) (British Columbia Ministries of Environment & Forest and Range)	Forest and Range Practices Act Industry certification requirement	All publicly-owned forest lands in British Columbia	Effectiveness monitoring and research. Post-logging assessments of vegetation characteristics, and riparian conditions Multi-taxa and habitat focus	Good communication (annual Chief Foresters report) but no clear link with policy and management	Monitoring requirement not in legislation and funding insecure Broad range of methods and good priority setting Still 'learning to monitor' rather than 'monitoring to learn' Limited use of reference conditions
Western Forest Strategy (WFS) (Western Forest Products)	Public pressure and industry certification requirement	Company owned or public timber lands	Mixture of projects using all monitoring types (apart from trend monitoring) and including research Multi-species, habitat monitoring Replicated experimental design in harvested and unharvested areas	Direct	Multi-species approach Clear objectives Good process for quick feedback to managers Small-scale and uncertainty around long-term security so little scope to examine long-term trends and cumulative impacts
Babine Watershed Monitoring	Bulkely Valley Land-	400 000 ha river	Effectiveness monitoring	Fairly direct	Excellent governance

Program (BWMP) (Babine Watershed Monitoring Trust)	use plan Industry certification NGO interest	catchment in the interior of British Columbia.	projects Vegetation, stand attributes Multi-taxa; population assessments for key species Adaptive management framework		Objectives and priority setting process clear but process to ensure results are used to inform review of plan and associated policy was not clear Cost- efficient program, but funding uncertain. Dependent on industry funding and NGO support
Alberta Biodiversity Monitoring Program (ABMI)	Industry certification and government policy (covers all natural resource industries)	All land tenures in AB	Trend monitoring for cumulative effects Vegetation; multi-taxa (2000 species); human impacts Remote-sensing and extensive ground sampling	Good communication via reports, brochures and web-site but no clear link with policy and management	Good governance Supported by all industries involved in natural resource use (not just forestry) and government Broad/landscape-scale, all land tenures Comprehensive habitat and species assessments on fixed sampling grid state-wide Needs to increase monitoring resolution to develop into a comprehensive effectiveness monitoring program Requires high-level commitment from government and industry

* See definitions in table 6 in Munks *et al.* (2010)

5. Discussion

The diversity of approaches to biodiversity management in the different jurisdictions covered in this review was reflected in the diverse array of monitoring programs with varying links to management (Table 1). The overseas review (Munks et al. 2010) found recent moves toward more ecosystem or landscape based management and more outcome-based management. It was concluded that the interest in and resources allocated to effectiveness monitoring in the different areas was a result of this change.

All programs recorded stand-level measures of habitat on the ground, but varied in the extent of reliance on remote-sensing or ground measurements of landscape effects. Jurisdictions varied widely in their approaches to assessments of species occurrences, with some programs recording detailed population information for a small number of high-profile species (e.g. NWFP program in Washington State and Oregon) while relying on habitat surrogates to predict likely changes in many other species. Other programs recorded directly the occurrences of large numbers of species representing multiple taxonomic groups (e.g. ABMI). The ways in which the effectiveness monitoring programs varied can be summarised as:

- location of sampling sites: targeted design (to answer a specific question), systematic design (grid) or random design
- replication versus sampling intensity
- entities being monitoring (e.g. stand structure, birds, all vertebrate fauna, fungi)
- how entities are being monitored: species distribution, persistence or abundance.

No monitoring design can feasibly encompass all ecological processes and species. Therefore the design of a monitoring program will affect the information it will provide. A number of researchers and managers both interstate and overseas made the point that there can be issues with identifying who is responsible for doing the monitoring and that monitoring is less important when optimal management action would not be altered by new information (Hauser et al. 2006). It was argued by some that targets for a monitoring program should be established a priori, with a response chain on how they will be used to adapt management already established (Hauser & Possingham 2008). Such targets are rarely set, because they can be difficult to establish.

On the basis of the overseas experience Munks *et al.* (2010) identify the following list of considerations that may help in the development and long-term security of biodiversity monitoring programs which effectively link with management:

- *good governance is important*
- *monitoring programs need to deal with funding risk (fluctuations in funding)*
- *clear objectives that reflect the holistic needs of the community are important*
- *the appropriate type of monitoring depends on the clarity and scale of the objectives*
- *the type of monitoring needs to be flexible to take into account the inherent complexity of monitoring wildlife and the variety of biodiversity management practices to be evaluated*
- *monitoring projects must address the temporal dimension*
- *monitoring approaches need to be co-ordinated and complementary*

- *values need to be kept separate from science when setting objectives, prioritising projects and reporting the results of biodiversity monitoring programs*
- *prioritise using a ranking method*
- *habitat surrogates are useful but are never the whole story*
- *sampling and measurements need to be closely aligned with objectives of user groups*
- *an agreed process linking monitoring to management decisions is important*
- *data transparency and communication at all scales with all stakeholders is important.*

Taking these into account, the desirable features of a program monitoring the effectiveness of a landscape approach to biodiversity conservation (including RFA priority species) in areas covered by the Tasmanian forest practices system would include:

- *A governance structure involving all stakeholders at national or state-levels (independent monitoring committee).*

  The best examples of successful biodiversity monitoring programs were those with a clear policy or legislative direction and those which operated at 'arms length' from government (e.g. associated with a university or occurring as a trust or institute, but with government representation on the board).

- *A clear alignment with management objectives.*

  Monitoring programs are most effective if sampling and measurements are closely aligned with the objectives, targets and reporting requirements of their principal user groups (i.e. government agencies and industry).

- *Tailor the type of monitoring to the clarity and scale of the objectives.*

  Broad-scale trend monitoring is the most appropriate response to broad-scale or fuzzy objectives such as those that are typically set in high-level policy statements. They may be the most cost- effective approach where objectives/targets are unclear at the finer spatial scale and variable in application across landscape, and where there is a need to take into account cumulative effects. This type of monitoring has been implemented successfully in parts of Europe (e.g. Kavanagh 2007) and more recently in New Zealand, but it remains a notable gap in many jurisdictions including Australia. However, broad-scale trend monitoring can never be a substitute for monitoring and research that address specific questions about the effects of particular management strategies.

  Where objectives are clear, the question-oriented approach seems to improve forest management most rapidly. The cost of this approach is that it may be difficult to maintain continuity of institutional support and funding for such 'operational-scale research' after the first-order questions have been answered. Another cost, if such a program is run instead of a long-term trend monitoring program, is that new sites will need to be established to address each subsequent round of management questions, thus losing the capacity to examine trends and cumulative effects across the landscape. Ideally, both approaches to biodiversity monitoring should be employed.

- *A ranking method to prioritise monitoring.*

  It isn't possible to monitor everything everywhere at every spatial scale. Monitoring is expensive and time is generally limited so what to monitor needs to be prioritised in a

manner that is transparent and comprehensive (Bunnell & Dunsworth 2009a; Price & Daust 2009) McComb *et al*., 2010).

- *A range of integrated effectiveness monitoring projects with designs that take into account the above considerations.*

  Effectiveness monitoring, by definition, must sample areas within which the particular management strategy is applied. However, it should not be limited to logged areas or those planned for logging in the near future (e.g. the FREP in British Columbia). Monitoring should also extend to control and reference sites outside of the logging area. This 'experimental' approach provides part of the operational feedback required to achieve true adaptive management. This approach may employ either retrospective sites or BACI (i.e. 'research') sites (McComb, 2010). Retrospective sampling is useful where there is a short timeframe in which to report on effectiveness of measures to meet ecological objectives and socio-economic objectives (e.g., in British Columbia land-use plan process).

- *Use of habitat surrogates and modelling.*

  Advances in computer technology have provided a wide array of tools to model habitats and distributions of plant and animal species. Such models can be used to extrapolate field data spatially or temporally, and to explore contrasting policy settings or management scenarios. Furthermore, the progression of other tools like LiDAR and satellite imagery may provide valuable information for monitoring programs.

- *A complementary state-level trend monitoring program involving biodiversity and land management agencies (forest management agencies).*

- *Identification of complementary research needs.*

- *An agreed process for reporting, feedback and communication to forest managers and other stakeholders.*

- *Connections to the management decision process should be given high priority early in the development of a program.*

We recognise a strong need for a coordinated and complementary set of approaches. A sound institutional framework is required to ensure appropriate mixes of different approaches, with intelligent degrees of flexibility.

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