Monitoring the effectiveness of forest practices to conserve biodiversity in western North America: lessons for Australian forest management

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A report to the Max Jacobs Fund Committee, the Forest Practices Authority, Tasmania, the Department of Industry and Investment, New South Wales and the Arthur Rylah Institute, Victoria.

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Disclaimers

The information presented in this report is a broad overview of the forest management policies and practices observed by the authors. 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. Only information considered relevant to the review was included.

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*Note that all authors contributed equally to the development of this report and the authorship order and information provided in the appendices may be altered to meet the different reporting requirements of each author and their agency/funding body.

Front Page Photographs

Clockwise from top right hand corner – American red squirrel at Smithers, British Columbia (S Munks), John Stadt and authors (SM, RL) in Alberta (R Kavanagh), Hairy Woodpecker, Smithers, British Columbia (S Munks), Old Western Hemlock tree in unlogged control site, Vancouver Island, British Columbia (R Kavanagh), variable retention logging, Private land, Vancouver Island, British Columbia (R Kavanagh), A. McKinnon and authors (RL, RK), Vancouver Island, British Columbia, Log raft, Vancouver, British Columbia (S Munks).

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The authors at Cathedral Grove in MacMillan Forest Preserve, Vancouver Island

Abbreviations and acronyms

ABMI	Alberta Biodiversity Monitoring Institute's program, 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 program applies to all land tenures in Alberta, Canada
BWMT	Babine Watershed Monitoring Trust, 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, Canada
FREP	Forest and Range Evaluation Program, which aims to determine the effectiveness of the *Forest and Range Practices Act 2004* in maintaining and conserving biodiversity on provincial lands in British Columbia, Canada
NWFP	US Forest Service's Northwest Forest Plan, applies to all federal lands in Washington and Oregon, with implications for state-owned and company-owned lands
WFS	Western Forest Strategy, implemented by a private companies (MacMillan Bloedel, Weyerhaeuser and Western Forest Products), which applies to industry-owned and leased lands on Vancouver Island, Canada

Note – all currencies in this document refer to the currency of the country where the project is located.

Contents

Summary

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.

We report on the results of a study tour to western North America where different approaches have been developed and applied in the past decade. We contacted and visited more than 60 scientists and managers associated with monitoring programs (both large-scale and small-scale), designed to inform the continual improvement of conservation measures for biodiversity, underway in the Pacific Northwest region of USA (Washington and Oregon) and Canada (British Columbia and Alberta).

We explored the approaches taken to forest biodiversity conservation, including the development of objectives in policy and plans, monitoring processes and systems, adaptive management processes, and examples. Problems relating to the ongoing success of the various approaches were also investigated. We learnt about a number of monitoring programs at different stages of development and implementation. Five main programs were chosen because they had all been in operation for at least five years and we were particularly interested to understand the processes and effectiveness of the feedback mechanisms and any evidence leading to improved forest management. We used a structured set of questions to begin our investigations, and a flexible approach to tease out the main issues of importance to us all.

The five main programs were:

- 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 2004* 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
- 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 program applies to all land tenures in Alberta.

We found that these five monitoring programs differed greatly in many respects, including their levels of funding, administrative support, organisational and land tenure complexity, their objectives and targets, the range of forest attributes and biota (taxa) assessed, the spatial and temporal elements of the sampling designs, the operational implementation, statistical rigour, feedback mechanisms, and their capacity to inform and report to forest managers and the general public about any adverse trends and cumulative effects that may require improvements to forest management practices to conserve biodiversity.

We were struck by the diversity and complexity of the approaches taken to the management of biodiversity in the different jurisdictions. This was partly a result of the diversity of land ownership and land management governance systems. This is reflected in a diverse array of monitoring strategies with varying links to management.

The monitoring programs visited ranged from large-scale, multi-agency, well-funded programs (e.g. NWFP, FREP) to smaller enterprises targeting specific questions of current management plans (e.g. WFS and BWMT). Other programs focussed on longer-term trend monitoring at the landscape-scale to provide the greatest flexibility to take into account cumulative effects and to report on known and unknown effects on biodiversity into the future (e.g. the ABMI program). The estimated current annual budget of the five main monitoring programs visited were; $50 K (BWMT); $500 K (WFS); $5 M (ABMI); $6 M (FREP); and $60 M (NWFP).

The WFS program was a good example of an effectiveness monitoring program which might also be classified as operational-scale research. Clear questions were answered with a rigorous sampling design, and feedback was immediate to managers who responded with improved management for biodiversity. While this program provided quick answers to the first round of important questions, there was less incentive for industry to continue this program to determine long-term trends and cumulative impacts on biodiversity.

The NWFP and ABMI monitoring programs had the necessary size, scale and infrastructure to provide ongoing and important information on state or provincial trends in species and habitat, and the cumulative effects of management. The NWFP focused mainly on changes in habitat quality (with associated extensive research to link these data to species), while ABMI focused mainly on changes in species occurrence and related these data to benchmarks in human impacts on the landscape and natural reference conditions.

The main drivers for effectiveness monitoring in western North America were the requirement to demonstrate progress in reporting for wood certification and other national or international agreements and, more broadly, to maintain the social licence to operate at state or provincial and federal levels. 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). The ideal governance structure appeared to be one in which values are separated from knowledge (e.g. BWMT and ABMI).

On the basis of this experience we 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.*

We also propose the following as desirable features of an effectiveness monitoring program for the forestry context in Australia. 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. We give prime consideration to our own states in Australia but also note that some of these approaches and considerations may have useful applications in many jurisdictions around the world. Our ideal system would include the following features:

- *a governance structure involving all stakeholders at national or state-levels*
- *a state-level trend monitoring program involving biodiversity and land management agencies (forest management agencies)*
- *a range of integrated effectiveness monitoring programs tailored for specific legislation and policy (e.g.* Tasmanian Forest Practices Act 1985*)*
- *independent monitoring committees involving regional stakeholders*
- *monitoring program designs that take into account the considerations provided above*
- *identification of complementary research needs*
- *an agreed process for feedback and communication to forest managers and other stakeholders.*

1 Introduction

A useful theoretical approach to conserving forest biodiversity involves a number of strategies to maintain habitat across multiple spatial and temporal scales in order to cater for different species (Caughley and Gunn, 1996; Lindenmayer and Franklin, 2002; Lindenmayer *et al*., 2006; Bunnell and Dunsworth 2009). This approach emphasises the importance of implementing measures to maintain habitat in off-reserve areas to complement reserve systems. This contrasts with both the traditional ‘set-aside’ approach to conservation and the primary aim of production forestry. Translating this risk-spreading approach into on-ground practice is often a difficult task for those involved in forest management. Success depends on a high-level of commitment by all involved to the overall goal of ecologically sustainable forestry.

A key component of this approach is the development of a monitoring and adaptive management process agreed to by all stakeholders to facilitate the continued development and improvement of conservation strategies (Walters and Holling 1990; Davies *et al* 2001; Lindenmayer and Franklin, 2002) (Figure 1). Management decisions need to be based on good information and their effectiveness needs to be monitored and researched, particularly when developed mainly from a mixture of expert judgement and practical experience. It is widely recognised that ongoing research and monitoring is important for the scientific credibility of provisions applied in forest management plans. Monitoring allows decisions to be based less on beliefs and more on facts (McComb, 2009).

A variety of different types of monitoring are recognised in the literature (see table 1). The two main types generally undertaken in forest management are:

- implementation monitoring which is used to determine whether prescribed management is actually conducted
- effectiveness monitoring which is used to determine whether the management specified has achieved its objective.

Both are extremely important for determining whether conservation management strategies are working. Implementation monitoring is generally a core legislative requirement funded from industry and government sources. Effectiveness monitoring, however, has only relatively recently been regarded by governments as a required activity. This is mainly due to a broader community requirement for a clear scientific basis for particular management actions. With the increasing public scrutiny of forest practices, the scientific basis for particular management actions needs to be clear. 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.

The importance of effectiveness monitoring was highlighted in a recent review of approaches taken to biodiversity conservation in areas managed for wood production in four states in Australia (Brown and Munks, unpublished data). Most states visited during this Australian review recognised the importance of monitoring the effectiveness of management actions and were grappling with the question of how such a monitoring program should be designed and implemented. There are few examples of such monitoring programs in Australia, although the Forestcheck project in Western Australia is proving useful (Abbott and Burrows, 2004). The development of such monitoring programs in other states is hampered by the lack of clear objectives for the management of biodiversity (Munks *et al*., 2009). Without explicit objectives it is difficult to formulate management actions or prescriptions and impossible to set measures against which the success or otherwise of these can be judged. Organisations are also often reluctant to allocate the necessary resources for large-scale, long-term monitoring programs unless there is evidence that such programs can deliver information in a timely and appropriate manner that will be relevant to a forest manager and regulators.

We report on the results of a study tour to western North America where different approaches to monitoring the effectiveness of management strategies for biodiversity have been developed and applied over the past decade or longer. The overall aim of this study tour was to visit relevant organisations to review the theory behind the monitoring programs, development of objectives, their design and implementation and adaptive management framework. The areas visited were similar to Australia in terms of having large areas of temperate forest and associated biodiversity as well as smaller forest patches in cleared agricultural landscapes. Parts of western North America are recognised as being progressive in terms of biodiversity management in production forests and a large amount of high quality research and innovative techniques have emerged from forest management agencies in this part of the world. The importance given to biodiversity management and conservation research and public concern about forest management and conservation are issues shared by this part of the world and Australian states.

A system that includes management strategies, monitoring and an adaptive management process agreed to by all stakeholders (figure 1), provides a useful theoretical framework to facilitate the continued development and improvement of conservation strategies and is a logical approach. However, as with most logical approaches, difficulties can arise when trying to be objective and systematic in applying theory to practice. We report on the western North American case studies to illustrate how others have attempted to apply the theory. We were particularly interested in how others approached one element of the adaptive management cycle – monitoring and particularly effectiveness monitoring. We report on examples of knowledge review, research, monitoring and processes leading to adaptation of management practices. The information we gathered illustrates the problems and complexities associated with bridging the gap between theory and on-ground practice and the variety of methods that need to be applied in different contexts – the need for flexibility. We provide a summary of practical considerations that have arisen from the case studies we review that may assist others in future monitoring initiatives. We also highlight the main problems that need to be overcome if monitoring results are to be useful and applied in the continual improvement of management actions.

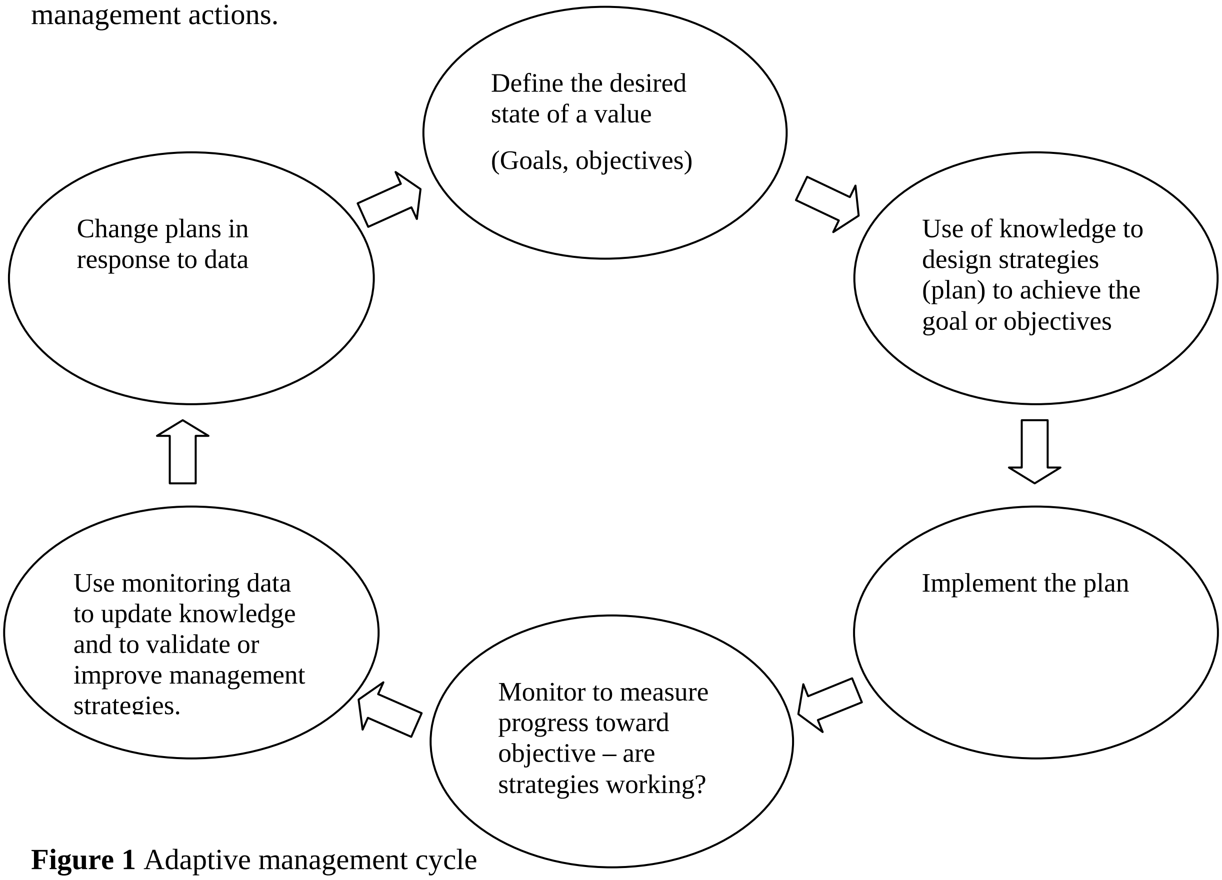

Figure 1 Adaptive management cycle

Table 1 Types of monitoring (adapted from Bunnell and Dunsworth, 2009, Paige and Darling, 2009, Price and Daust, 2009, McComb *et al*., 2010)

Type of Monitoring	Description
Baseline, status, surveillance and trend monitoring	Used to acquire information on the condition of a resource value. Usually involves multiple surveys over time or across an area to examine the condition of a particular value. Can help to explain results of effectiveness monitoring program eg., decline in spotted owl not necessarily because NWFP not working but because monitoring found that barred owl populations on increase.
Implementation (including compliance) monitoring	Have we done what we said we would do? Records whether or not management actions in plans to meet particular objectives are being applied (eg., were the required number of hollow-bearing trees retained in a harvest area? Were landscape level retention targets applied?)
Effectiveness monitoring (targeted monitoring)	Did our actions achieve our objectives? Used to determine whether the management actions are effective (eg., are hollow-using fauna maintained in a harvest area with current rates of retention of hollow-bearing trees? Is species diversity maintained across the landscape with current landscape level retention targets?)
Validation monitoring	Investigates the relationship between management actions and objectives (eg., are hollow-using fauna maintained because of stand-level management actions?). Improves knowledge and has a fuzzy boundary with research. May be retrospective approach or Before-After-Control-Impact design. Trend monitoring can also be part of this. Cause-effect establishment. Helps inform uncertainty level

2 Methods

A three week study tour was carried out during April and May 2010 to gather information on monitoring the effectiveness of approaches taken to conserve biodiversity in areas subject to production forestry activities in North America (appendix A). Appropriate organisations to visit were selected in the months prior to the trip using information available on the internet and in the literature. Existing contacts were also used as a source of information. All of the people and organisations approached responded to the initial request to visit. We contacted and 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 north-west region of USA (Washington and Oregon) and Canada (British Columbia and Alberta).

We explored the approaches taken to forest biodiversity conservation, including the development of objectives in policy and plans, monitoring processes and systems, adaptive management processes, and examples. Problems relating to the ongoing success of the various approaches were also investigated. We learnt about a number of monitoring programs at different stages of development and implementation. The organisations and individuals were selected based on their involvement in long-running, established programs. Figure 2 illustrates the locations visited during the study tour.

We used a structured set of questions to begin our investigations, and a flexible approach to tease out the main issues of importance to us all. The questions were sent to the key people in each organisation prior to the visit (appendix B). These questions facilitated discussions about how biodiversity is managed in wood production areas across land tenures, how goals and objectives are measured, how the effectiveness of measures for the conservation of biodiversity is monitored, how new information is taken into account in on-ground management and the costs, governance and communication of the monitoring effort.

The information gathered during the meetings and field visits was supplemented by reports and unpublished information also gathered during the trip or via the internet. A review of the literature provided some of the scientific information for this review. However, since much information is unpublished, hidden in agency reports, guidelines or in the experience of individuals involved, the majority of information reported on was gathered during the study tour from the scientists, forest managers and field practitioners visited.

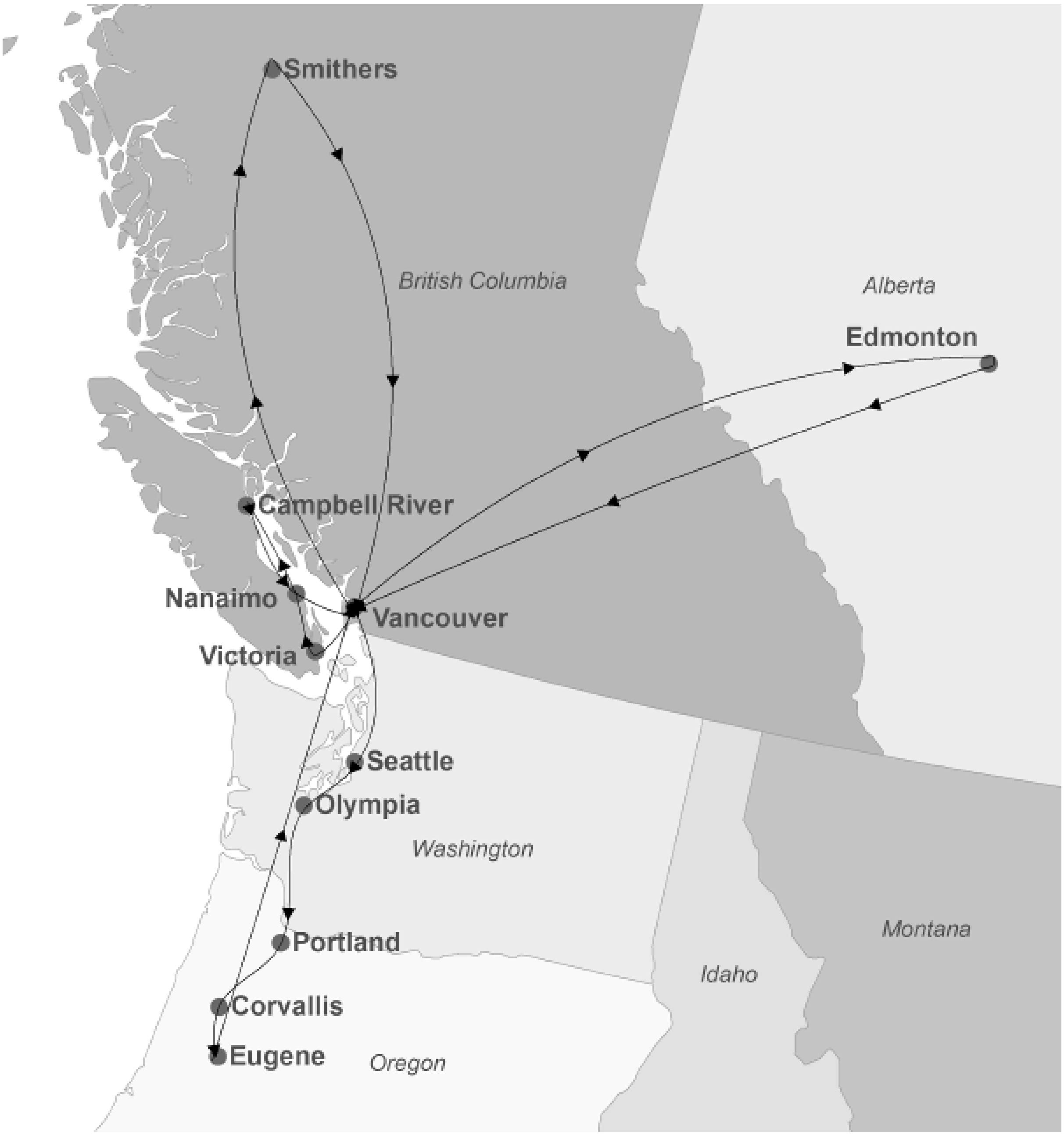

Figure 2 Locations visited on study tour. See appendix A for contacts at each location.

3 Results – approaches to monitoring the effectiveness of strategies for biodiversity conservation

Eighteen different organisations in three different regions in western North America were visited during the study tour (figure 2 and appendix A). 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. Our review focuses 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
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- 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.

The elements of the biodiversity that we were lucky enough to encounter on our trip are listed in appendix D.

3.1 Washington and Oregon

3.1.1 Forestry context

The two north-western states of USA (Pacific North-west) support extensive forests, and forest industries have contributed substantially to their local economies. Washington State covers an area of 18.2 million hectares south of the Canadian border, and Oregon covers 25.2 million hectares between Washington to the north and California to the south. Most of the remaining forests are in the hills and mountain ranges in the western parts of each state, including the Coast Range and the parallel Cascade Range further inland. The intervening valley is heavily settled and developed for agriculture and industry, while the eastern parts of each state are in rain-shadow and sparsely settled. The roles of forest industries in the state economies have declined with increasing prosperity from agriculture, industry and other modern business.

Most of the remaining forests are coniferous, dominated by species such as Douglas fir, western hemlock and sitka spruce, often growing in complex mixtures of species. Lodgepole pine becomes dominant in drier forests further east. Deciduous trees such as aspen and poplar grow along streams and in swampy areas, and some of them also proliferate as pioneer species after fire or logging. Extensive stands of deciduous Garry oak (*Quercus garryana*) occupied the fertile valleys in the past, but were quickly cleared for agriculture following European settlement: this ecosystem is now represented mainly by small remnant forest patches (Figure 3). The coniferous species are the main source of timber for sawlogs and pulpwood.

Fire and wind-throw are the main natural agents of disturbance, along with grazing by ungulates (mule deer, elk, etc – see figure 4) and locally volcanic eruptions (e.g. Mt. St. Helens). As in Australia, fires have highly variable effects, depending on factors such as intensity, frequency and dominant tree species. Some coastal forests rarely burn and are more likely to suffer wind-throw than fire (e.g. on the Olympic Peninsula). Other wet forests in the mountains tend to experience occasional severe fires, with substantial tree mortality (as with ash forests in Australia). Drier forests of lodgepole pine in the east experience frequent fires, which often just burn the understorey with little or no mortality of mature trees (as with mixed-species eucalypt forests in Australia). Indigenous people used fire to manipulate forest structure and regeneration, and to promote hunting opportunities and growth of food plants (e.g. camas lily, which prospers in open woodland or grassy areas and produces a nutritious tuber). As in Australia, little is known about the details and degree of sophistication of these management systems. They are likely to have had more impact in the fertile valleys (where most people lived) than elsewhere.

Forest management is complicated by a complex system of land tenures, involving three tiers of government (federal, state and local) and private landholders. In addition, there are systems of federal and state reserves (e.g. national and state parks) and indigenous land. Two federal agencies are involved in managing national forests, the Forest Service and the Bureau of Land Management. State agencies manage the state forests and set standards for managing forests on all land under their jurisdiction. Local governments play a lesser role in forest management but receive royalties for timber sales from local state forests: in some cases they are heavily reliant on this source of income.

As in many parts of the world, most of the National Parks and State Parks are in montane environments with high scenic values and low potential for other economic use. Many of the wet mountain forests are on federal land, while state forests tend to occupy the foothills. Some areas of state forest are leased to private forest companies under long-term lease arrangements. Most of the lowlands are in private ownership, and most of the forest has been cleared. However, some reserves have been maintained, and a national NGO, the Nature Conservancy, has taken a lead in identifying and purchasing samples of under-conserved ecosystems such as Garry oak woodland. In one part of Oregon, far-sighted local governments established a series of local reserves on a grid basis, in the early days of settlement. This has produced a patchwork of small blocks of retained vegetation and cleared farmland, and efforts are now being made to consolidate some of the blocks to form more viable reserve systems in line with modern thinking.

Clear-felling was the preferred method of timber extraction for many decades, and aroused all the controversies that have challenged the timber industry worldwide where this method is employed. Some of the most well-publicised standoffs between conservationists and loggers occurred in these states, especially in the 1980s. In response, there have been large reductions in the area available for timber harvesting, and an increased diversity of harvesting strategies. These involve various approaches that aim to better mimic effects of natural disturbance, thereby increasing structural heterogeneity across the forested landscape mainly by retaining trees or groups of trees on logged coupes.

Regeneration is achieved mainly by planting nursery-grown seedlings. This contrasts with Australia, where natural regeneration is the most common method, sometimes supplemented by broadcasting previously collected seed. Various research projects have been undertaken to compare methods (e.g. by Richard Bigley in Oregon), and they show few floristic differences between planted and naturally regenerated sites (R Bigley, pers. comm.). However, planting provides the forest manager with a high degree of control over the nature of the regenerating overstorey, with the power to ensure desired mixtures of tree species. Whether they resemble the natural mixtures (or other mixtures desired by the community, e.g. for landscape aesthetics) is not well established: deciduous pioneer species tend to be of low value for timber, and may be selectively disfavoured. Planting is more expensive than natural regeneration, but it produces a more reliable stocking rate. Logging contractors are obliged to achieve specified stocking rates within about ten years before they can declare logging coupes regenerated and move on to the next round of proposed coupes. Hence there are greater financial risks for them in leaving regeneration to natural forces, than in electing to invest the extra for planting with its greater assurance of meeting these targets. So current forest policy is the main driver for planting to be used, and this is surely influencing the nature of the regenerating forest throughout the Pacific north-west. Further research on the effects of planting on the nature of the regenerating forest (overstorey, understorey and fauna) would seem to be needed to establish whether this policy setting is delivering the ecological benefits that the community may expect. Further research on the nature of community expectations may be needed as well.

Figure 3 Remnant patch of Garry oak woodland near Corvalis, Oregon (Photo: Richard Loyn)

Figure 4 Mule deer(black-tailed) Mt Ranier, Washington State (Photo: Richard Loyn).

3.1.2 Legislation and policies for biodiversity conservation

The environment movement focused its efforts strongly on federal lands (national forests), where federal legislation (notably the *Endangered Species Act 1973*) provided a powerful tool to modify forest practices and reduce the extent of industrial forest management. The Act applies specifically to federal lands. (This contrasts with Australia, where a hierarchy of federal and state laws apply on all land, and federal land management legislation tends to be weaker than state legislation, reflecting a long-held view that states have the prime responsibility for land management and conservation issues). The community used this legislation to halt all logging in national forests through court cases resulting in a court order in 1991, based mainly on the need to conserve old-growth habitat for northern spotted owls (Thomas *et al*. 2006).

This situation aroused the attention of government at the highest levels, culminating with an edict by Congress under President Bill Clinton, to fix the problem by developing a Northwest Forest Plan (NWFP). (We were struck by a remarkable parallel with the Australian situation, where then Prime Minister Paul Keating demanded more certainty in forest planning through a process of Regional Forest Agreements or RFAs.) A set of alternative options was prepared in a very short time (three months) by a group of academics and bureaucrats led by Professor Jerry Franklin from Washington State University and Jack Ward Thomas from the Forest Service, who were highly regarded as innovative, influential and even-minded thinkers on forest management issues. Initially 34 options were devised and these were then whittled down to ten. The plan drew on extensive previous work by many scientists, including a specific plan for managing northern spotted owls, prepared in 1990 under the leadership of Jack Ward Thomas (Thomas *et al*. 1990, 1993, 2006). One of the options was then selected for implementation, and it became the NWFP, accepted by Congress in 1994. The plan applied 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) (figure 5). These included 7.9 million hectares in 19 national forests, 1.1 million hectares in seven Bureau of Land Management districts, 0.9 million hectares in six National Parks and 0.07 million hectares of land managed by the Department of Defence.

The NWFP was far-reaching in its effects on management of national forests, and on forest management philosophies more broadly. It is beyond the scope of this report to analyse these matters in detail. The main points are that 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.

The plan was based on five key principles:

- never forget human and economic dimensions of issues
- protect long-term health of forests, wildlife and waterways
- focus on scientifically sound, ecologically credible and legally responsible strategies and implementation
- produce a predictable and sustainable level of timber sales and non-timber resources
- ensure that federal agencies work together.

The plan considered protection of old-growth values and aquatic ecosystems (especially the valuable salmonid fisheries) as well as threatened forest species. Two federally listed vertebrate species were particularly influential in development of the Plan and subsequent forest management. Both were birds, and both are active in forests mainly at night, but otherwise they could hardly be more different in basic ecology. One was an owl, the northern spotted owl *Strix occidentalis caurina*, which inhabits old-growth coniferous forests (and some other forest types elsewhere in its range), taking a range of prey dominated by arboreal and terrestrial forest mammals (figure 6). Northern flying-squirrels *Glaucomys sabrinus* are the main prey in coniferous forests and dusky-footed woodrats *Neotoma fuscipes* are important in deciduous forests further south.

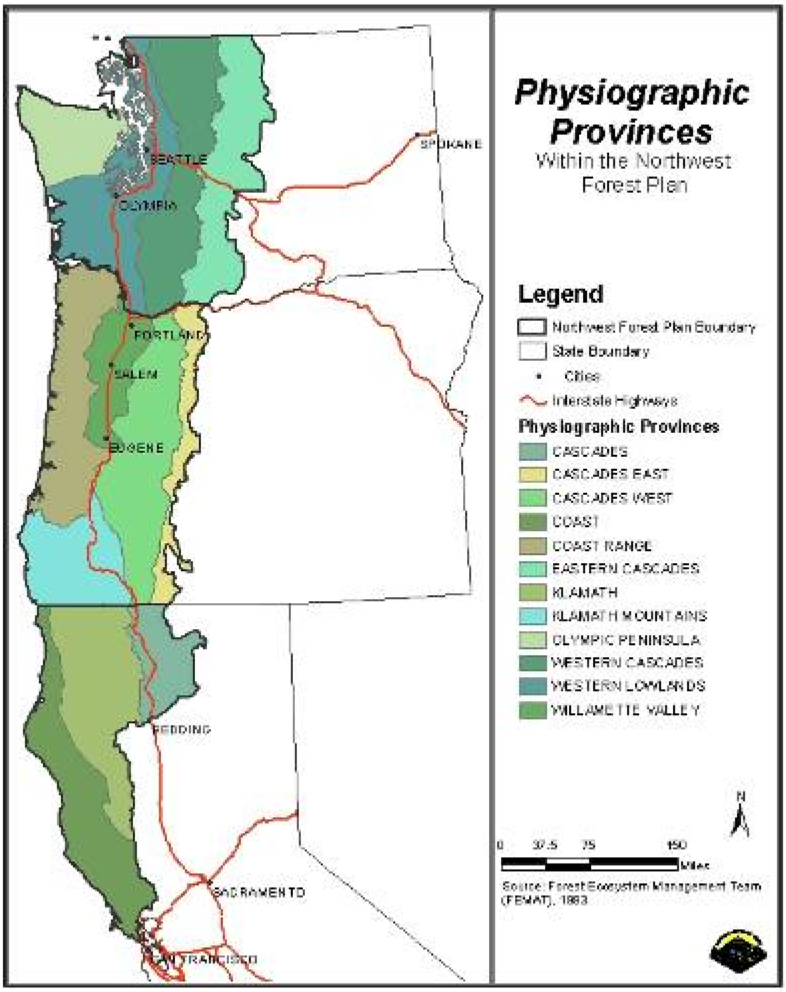

Figure 5 Physiographic provinces in area covered by NWFP. These provinces are classified by their differences in climate, vegetation, geology and landforms (from Rapp, 2008).

Figure 6 The northern spotted owl *Strix occidentalis caurina* at Cascades Raptor Centre, Eugene, Oregon (Photo: Richard Loyn).

The other listed species, somewhat bizarrely, was a seabird, the marbled murrelet *Brachyramphus marmoratus*, which feeds on fish in offshore waters but uses old-growth forests for nesting, where it lays its eggs on mossy horizontal branches high in the canopy of coniferous trees. The murrelets fly in to their nests after dark to avoid predation from diurnal terrestrial predatory birds, and they may fly up to 80 km from the coast to access suitable nest sites. Both species have a broader range of habitat requirements in other parts of their range: marbled murrelets will nest on rocky coastal screes in southern Alaska, and northern spotted owls will nest in regrowth Californian redwood forests and in small patches of oak forest in California (different subspecies), but in the Pacific north-west they are strongly dependent on old-growth forests. Paradoxically, surveys of the nocturnal northern spotted owl are best conducted by day (using call playback and live mice to lure them into showing themselves) and nest surveys of diurnal marbled murrelets are best conducted at night (listening and looking for them flying into nests after dark). (Owls were also very influential in the development of Regional Forest Agreements in Australia, because of their position in the food-chain and requirements for large areas of mature forest, rather than for legislative reasons.)

3.1.3 Development of objectives and management strategies

Before the development of the NWFP, the timber industry had played a dominant role is setting objectives and management strategies for forests on public land. This proved unacceptable to the community, who used federal threatened species legislation to challenge this approach in the courts. This resulted in much greater weight being given to ecological and social objectives, rather than purely economic objectives as determined by the timber industry. However, even the much-celebrated NWFP and its associated goals and objectives did not meet all the requirements of the community (Thomas *et al*. 2006). Standoffs and court challenges continued where logging was proposed in national forests, and these have continued to reduce the amount of logging in national forests to very low levels. Logging in national forests is now applied mainly in attempts to achieve ‘ecosystem restoration’, using thinning, to speed up the development of large trees in some areas.

Similar issues have applied to state forests and private land, but with different legislative obligations. Logging continues but in response to community demand, clear-felling has essentially been replaced with a range of harvesting strategies such as variable retention or ‘clear-felling with reserves’ (figure 7). Recently authorities in Oregon attempted to revert to clear-felling in some of their state forests, partly in response to calls from local government for increased revenue. However, public outcry and court cases prevented these revised plans from being put into effect. Objectives and management strategies to conserve habitat for northern spotted owls and marbled murrelets also apply to state forests and private land. Managed actions for these species depended mainly on field surveys and reservation of areas of forest occupied by each species. Various attempts were made to define the number of areas to be protected, but in practice the power of the federal Endangered Species Act did not allow any area to be logged where these species were known to be present. Attempts to use habitat values as surrogates for species surveys were rarely found acceptable when tested in court. Hence no area of federal land could be logged until a specified amount of survey effort had been applied to determine whether or not the species was present. It is now estimated that ~80% of forests are in different categories of reserve and 20% are available for logging.

It has been argued that the emphasis on just two threatened species cannot do justice to the myriad requirements of multiple species. This may not be a problem for species that are reasonably well known and common, but what about all the other species (especially invertebrates and amphibians) for which little is known? To address this, a program has been instigated called ‘Survey and manage’, in which searches are conducted for rare or little known species on proposed logging coupes (Molina et al. 2003, 2006; Molina and Marcot 2007; Raphael and Molina 2007). We heard several criticisms of the program, related to design aspects (no surveys in reserves, guaranteeing that species believed to be rare are more likely to be found in areas proposed for logging than elsewhere) and poor communication between survey teams and forest managers. However, we also heard praise for the program as it has greatly increased our knowledge of some of these poorly studied groups. The lack of data from reserves may be balanced to some extent by the use of modelling to predict species distributions over broad areas including reserves (Suzuki *et al*. 2008).

Figure 7 Clear-felling with reserves in mixed conifer forest on state forest at foothills of cascades, Washington State. Coupes are approximately 40ha and trees left in clumps or as individuals. Harvested areas are replanted with Douglas fir and western red cedar (Photo: Richard Loyn).

3.1.4 Approaches to effectiveness monitoring

At the species-level, effectiveness monitoring is targeted very much at evaluating whether or not the strategies delivered by the North West Forest Plan are effective at maintaining populations of the key focal species, Spotted Owl and Marbled Murrelet (Lint *et al.* 1999; Mulder *et al*. 1999). Northern spotted owls are surveyed comprehensively, with most known territories visited annually to assess occupancy and breeding success. The owls have proved surprisingly obliging to study, as they readily fly out of their hollows by day in response to call playback or human imitations of their call. This behaviour has been reinforced through routine rewards of live mice, fed to responding birds. Often they are quite easy to catch by hand, in marked contrast to many owl species round the world. Many birds have been marked and radio-tracked to determine longevity, home range, dispersal and other demographic variables. Different types of modelling (demographic, PVA and limited habitat modelling) have been applied to help predict management outcomes. This all builds on the sophisticated initial body of demographic data, based on early work by Eric Forsman and his colleagues. We heard some dissenting voices about the cost of this continuing work, but we were told that less invasive methods (e.g. nocturnal playback surveys at samples of sites) would cost similar amounts of money if executed with similar rigour. The cost of monitoring northern spotted owls has been estimated as $70m since the 1980s, with current budgets of $4m/year for northern spotted owls, $0.5m/year for marbled murrelets and $0.6m/year for old-growth forests.

Marbled murrelets are surveyed at potential nesting sites to assess areas planned for logging, at least two or three years in advance of proposed logging. However, this is unlikely to give a comprehensive picture of their breeding numbers and distribution: indeed, we heard the view that their nest-sites are much more widely distributed than initially thought. The main monitoring tool is to assess their abundance when feeding by day in offshore waters, using distance sampling from boat-based transects. All seabird species are assessed during these transects, and this is the only program we encountered in Washington and Oregon that involved routine monitoring of a wide range of species (paradoxically seabirds not forest species).

Monitoring of both the main target vertebrates of the NWFP have declined in recent years. Northern spotted owls have declined precipitously and this has coincided with invasion by barred owls, a similar but larger species that was formerly confined to North America east of the Rockies. Barred owls are generalists, taking many birds, frogs and insects in their varied diet, and are not limited by a sparse population of hollow-dependent northern flying-squirrels. Most scientists think that the barred owl expansion has contributed to the decline in northern spotted owls. However, others think that continuing deterioration of habitat may be the prime reason. (The expansion of barred owls was detected in the course of monitoring northern spotted owls, and had also been noticed by amateur observers in habitats not occupied by northern spotted owls. It is likely that a more broadly based monitoring program would have detected this issue at an earlier stage, perhaps allowing a greater range of management responses.) Marbled murrelets are also showing a slow but steady decline (~3% per annum), consistent with gradual loss of old-growth nesting habitat. Other seabirds monitored in offshore waters did not show this decline: this shows the value of monitoring ‘control groups’ as well as species of direct interest.

There is no regular monitoring of other elements of the biota, in relation to forest management. Some research is conducted on arboreal voles, but hardly any on other forest mammals (E. Forsman pers. comm.). This is partly because some species carry disease and extreme precautions need to be taken when handling them (e.g. protective clothing). Nevertheless, we were surprised that so little current work seems to be in progress on species such as squirrels (many of which are diurnal and easily surveyed) or species that form the main prey base for northern spotted owls (northern flying-squirrels and, in the south part of the range, dusky-footed woodrats). We were also surprised that little is being done on songbirds, which are easily surveyed and species-rich (hence highly informative about a range of ecological processes). 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.

More comprehensive research programs have been conducted in specific locations, including the HJ Andrews Long Term Ecological Research site. This has included some impressive work on invertebrates, amphibians and other groups that often receive little attention. However, the gap remains for common forest mammals. Songbirds have received some attention but warrant much more, in view of the high yield of data per unit effort of fieldwork. A major study of the effects of thinning on biota has been conducted in the forests of western Oregon (D Olson pers. comm.).

Old-growth forest monitoring is mainly done by remote sensing, but it links with a plot-based monitoring project run and funded separately by the USDA Forest Service. It uses Landsat imagery (now freely available to the public). The monitoring shows that 30–35% of forests in the Pacific north-west can be considered to be in old condition, compared with ~60% before European settlement The ‘remote sensing change detection project’, however, shows that the age structure of the forest in the NWFP area is increasing as less harvesting (M. Moeur pers. comm.).

Broad-scale and extensive monitoring of aquatic systems is also being carried out by scientists in the USDA 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.

Routine implementation monitoring (or compliance monitoring) is conducted to ensure that management actions prescribed in policy and legislation are applied in state forest. However, very little work has been done to assess the effectiveness of those prescriptions for conserving a broad suite of forest fauna.

3.1.5 Adapting management

Management strategies for northern spotted owls have been revised periodically in light of new information (Spies *et al*. 2006). A marked change of approach was made at an early stage in response to demographic modelling that showed the need for clustered reserves for the species, to minimise mortality of juveniles dispersing through hostile habitat (Thomas *et al*. 1993). Tactical adjustments can be made to the reserve system in light of new information about occupancy by the species. However, logging is rarely allowed in habitat previously occupied by northern spotted owls. The species has declined markedly in recent years, and few new occupied sites have been found in national forests. Plans for logging in state forest often need to be revised in response to new records of northern spotted owl (or marbled murrelet). Competition with barred owls has emerged as a new issue, and calls have been made for direct action to address it by shooting barred owls. This raises many ethical issues, as barred owls are a native species and it could be argued that their invasion is a natural event.

Some attempts have been made to manipulate habitat structure to benefit northern spotted owls, using fire and logging, but they remain experimental. We are not aware of any concerted efforts to overcome shortages of hollows for the owls or northern flying-squirrels (their main prey species) by providing artificial hollows (nest-boxes). This could be worth exploring further. Perhaps the most beneficial approach would be to use small nest-boxes for northern flying-squirrels in northern coniferous forests (where owls may be limited by their main prey), and large nest-boxes for owls in southern deciduous forests (where dusky-footed woodrats provide abundant prey but owls may be limited by availability of suitable nest sites). Nest-boxes for owls could also facilitate more socially acceptable approaches to managing barred owls, e.g. by pricking eggs of any barred owls that were found to use the nest-boxes.

Adaptive management for marbled murrelets is even more fraught with difficulty. Suggestions have been made that artificial mossy breeding platforms could be provided for the species, but there are immense logistical difficulties in installing such platforms high in the forest canopy. As with northern spotted owls, plans for logging in state forest often have to be revised in light of new records of marbled murrelet. General thinking seems to be that the species will continue to decline for some years with inevitable attrition of old-growth forest (e.g. from windthrow), and then recover as older regrowth is allowed to mature. There is much uncertainty about how old a stand needs to be to supply suitable nest-sites for the species.

We expected to hear about a lot of research on the effectiveness of new approaches to harvesting, such as clear-falling with reserves, in terms of their benefits and costs to flora and fauna. We are sure some has been done, but perhaps our focus on 'monitoring' may have deterred some correspondents from describing more targeted research projects. There are obvious research projects needed to determine the value for flora and fauna of small patches of retained forest in logging coupes at various times after logging. Comparisons need to be made with similar parcels of retained forest embedded in unlogged forest, and with logged coupes of various ages that lack such retained patches. Some experimental work of this sort is underway in British Columbia, but we did not encounter it in Washington or Oregon, except in relation to thinning.

The concept of adaptive management was developed largely in North America (Walters and Holling 1990; Bunnell and Dunsworth 2009) and we expected to find more formal examples of its implementation than we did. Instead we found lots of forest managers who needed to adapt their management frequently in response to changing policy (itself reflecting changing community demands), and lots of forest ecologists who strove to understand the systems (or selected species that relied on those systems) and use their knowledge to guide the way we think about forests and hence manage them. There was good feedback to forest managers from some of the forest monitoring programs (notably on northern spotted owl and marbled murrelet) and calls for improved feedback from others (notably the Survey and Manage Program). But the main barrier to really adaptive management was that the collection of forest monitoring programs was too narrow, and could not give a holistic view of how the forest ecosystems were travelling. Hence forest managers were only able to respond effectively to narrow aspects of community concern. The one attempt at a broad approach (the Survey and Manage Program) dealt explicitly with rare and little-known species. One of the reasons they are little-known is that the community may have less interest in some of these groups than in more conspicuous elements of the forest flora and fauna, such as trees, shrubs, mammals and birds. We tentatively conclude 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.

3.1.6 Strengths and weaknesses

The NWFP is an outstanding example of a quick and radical response by government to a major shift in public demands for changed forest management. Some key ingredients in its acceptance included:

- the high public standing and esteem of the main players, who were trusted as even-handed and objective, and their close connections to the highest levels of government including the President (Bill Clinton)
- the quality and quantity of research already done on key species, especially northern spotted owl
- the prosperity of the community, backed up by the economic clout of the nation, which allowed a major reduction in forest logging to be put into effect, arguably within acceptable levels of local economic disruption.

The monitoring of northern spotted owls was shaped very much by the opportunities provided by previous intensive demographic research. This is both a strength and a weakness. The research is impressive, and could not have been conducted at this level in a less prosperous country, or with a less obliging species. However, it may have locked researchers and forest managers into a particular paradigm, and inhibited a more holistic view of the environment including processes acting on prey species (especially northern flying-squirrels) and potential competitors (especially barred owls).

We were impressed by the marine monitoring of marbled murrelets, and in particular the fact that the program gave data on multiple species. This helped distinguish effects of forest management (affecting only marbled murrelets) from the multitude of other variables that affect the marine environment.

The overall monitoring effort has two major limitations, which may have had adverse effects on the ability of forest managers to respond adaptively to meet their objectives for conserving flora and fauna. 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 new harvesting methods such as clear-felling with reserves (at least not in a systematic way). We believe these limitations could be easily overcome, and should be avoided in any new programs that are designed in other jurisdictions such as Australian states.

3.2 British Columbia

3.2.1 Forestry context

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 (Figure 8, Ministry of Forests and Range, 2006). These forests are predominantly coniferous (83%), 6% are mixed forest, 6% are broadleaved, and the remaining 5% are regenerating forests with no species yet assigned (Ministry of Forests and Range, 2006). Lodgepole pine, spruces and true firs are the most widespread trees.

About 5% of the province's forests are on private land and the remaining 95% are publicly owned, with approximately 10% in reserves, protected by the national and provincial governments. In 2000, about 0.2% of the private land was granted to First Nations (Ministry of Forests and range, 2006). (Statistics available for 2006 state that reserves include 15% of the province's forests over 140 years old and 19% of forests over 250 years old, Ministry of Forests and range, 2006). The Coastal Douglas fir, ponderosa pine and interior Douglas fir zones have the lowest representation in the reserve system, each with 5% of forests protected. These zones are the warmest and driest of the forested biogeoclimatic zones recognised in British Columbia and are hence the areas where human settlement is greatest. Only two per cent of the province's land area, however, has been converted to intensive human use, mostly at lower elevations and particularly along valley bottoms. This permanent change has impacted on wildlife, as lower elevations often encompass areas with the most productive soils and highest biodiversity. As found in Washington and Oregon, the dry, open Garry oak woodland seen on our visit is one lowland forest community that is now rare.

Wildfire, windthrow, insects and diseases are all natural disturbance factors that occur in the forests of British Columbia. The degree to which these factors operate in different areas varies. For example, we learnt that the main disturbance factor on Vancouver Island is wind, not fire. We saw extensive evidence of the current mountain pine beetle epidemic affecting lodgepole pine in the area surrounding Smithers (Figure 9). This outbreak has been enabled by climate change and is forecast to disturb an average 2 million ha per year between 2001 and 2050 (Ministry of Forests and Range, 2006). European immigrants and other non-aboriginal residents have altered the rate of some natural disturbances (e.g. fire suppression) but have also affected the forests through their dependence on forest resources. One major effect of logging is a shift from the predominance of older forests to a landscape dominated by younger forest (Pojar and McKinnon, 2004). Despite the changes resulting from human land-use activities, however, 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 and McKinnon, 2004). The challenge for most of the forest management agencies we visited was to make sure this continued into the future.

Approximately 41% of British Columbia's vascular plants and terrestrial vertebrates are recorded as being forest-associated, including 721 vascular plants, 303 birds, 189 mammals, 81 freshwater fish, 20 amphibians and 10 reptiles (Ministry of Forests and Range, 2006). It is estimated that around 36% of these species are dependent on habitat provided by old-growth or mature forest. The Committee on the Status of Endangered Wildlife in Canada lists 91 of British Columbia's forest-associated species as endangered or threatened, and protection is provided for 76 under federal law. The largest numbers of threatened species occur in the biogeoclimatic zones with the lowest proportion of reserves. Timber harvesting is reported to be a major threat to 33 or more of these species, including the coastal giant salamander, elk, marbled murrelet and spotted owl.

About 40% of the forested area in British Columbia is available for timber harvesting. About half of these forests are a mix of older and younger forests originating from natural disturbances, and have never been harvested. The remaining half are younger forests that have regrown after timber harvests, and some of these are now being harvested a second time (Ministry of Forests and Range, 2006). Canada's forestry sector employs approximately 280 000 Canadians, and roughly 300 communities are dependent upon the forestry sector (2006 stats from British Columbia stats web site). The British Columbia Forest Service (BCFS) is the main government agency responsible for stewardship of about 50 of the province's 59 million hectares of forest. This enables more regulatory control, however, much of this forest is leased by the Crown to private companies (Tree Farm Licenses – TFLs). Most operational management planning decisions – planning for timber harvests and other resource values, reforestation, building roads and controlling wildfires – are made by the private companies. Oversight by several government agencies, including compliance monitoring by the Forest Practices Board, helps with accountability to the public. The government sets the allowable annual cut and timber harvesting rights are allocated to companies. The average total timber harvest is in the 60–80 million m^3 per year range (Ministry of Forests and Range, 2006).

Silvicultural systems traditionally used include clearcutting and a variety of partial harvest techniques. However, more recently there has been a move toward clearcutting with reserves and variable retention systems (figure 10) to try and better achieve a balance between biodiversity objectives and wood production objectives (Bunnell and Dunsworth, 2009). There is also a move toward smaller clearcut coupes (20–30ha) although we observed significantly large ones in the interior of British Columbia and on private land. Most areas we observed had been reforested after harvest through planting of native species. Compared with natural regeneration, planting is reported to increase harvestable volume by about 15%, and about 25% with the use of select seed (Ministry of Forests and Range, 2006). However, as reported above for the similar practice in Washington and Oregon, the degree to which such active regeneration alters the species mix of the native forest is of concern and is unknown.

Figure 8 Extent of forests in British Columbia in 2000 (from Ministry of Forests and Range, 2006)

Figure 9 Evidence of the current mountain pine beetle epidemic affecting lodgepole pine in the area surrounding Smithers (Photo: R Kavanagh).

Figure 10 Example of variable retention in higher elevation forest (Western red cedar, western hemlock, Douglas fir, Amabilis fir etc.) in the north of Vancouver Island (Photo: S Munks).

3.2.2 Legislation and policies for biodiversity conservation

3.2.2.1 The Forest and Range Practices Act 2005 and Land Act 1996

Forest management practices were highly regulated in British Columbia by a prescriptive code developed in the early 80s in response to public concern over the rate of harvest and loss of old-growth forest. However, more recently, in 2004, a change of government resulted in the replacement of the *Forest Practices Code of British Columbia Act 1995* with the *Forest and Range Practices Act 2005*. This resulted in the subsequent replacement of the prescriptive code with a more result-based system 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 (see example in appendix C) and professionals (foresters and forest managers) are relied upon to develop ways to meet these desired outcomes. This approach is known as ‘professional-reliance’ and it cut the cost of regulation by a third. Although most people we spoke to (forest scientists, managers and practitioners) agreed that the previous code of practice had been overly prescriptive and restrictive they felt that this alternative approach has set the bar too low and noted that many forest managers still rely on the old code prescriptions and guidelines (eg., Biodiversity Guidebook, 1995) when trying to meet the requirements of the new regulations. In the words of one scientist we spoke to – ‘professional *reliance is a good idea, but professional responsibility is frightening for most*.’

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 legalize 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. A number of different forms of land-use plans have been used to provide direction for the management and allocation of public lands and resources. Generally, they provide the vision, approach, goals, objectives and broad direction for achieving sustainable land and natural resource management across the landscape in a given geographic area. Land-use agreements are a tool through which governments – normally the province and First Nations – agree to implement a particular land-use plan, or to implement land-use direction contained in the agreement itself. This process is managed by the Integrated Land Management Bureau.

A policy framework for landscape reserve planning has also been developed which provides the commitment to spatially locate the legally-required old forest retention targets, in conjunction with focal species habitat, and also includes the commitment to manage at ‘no higher than high risk’ (given that the retention targets range from 30–50%-70% of range of natural variation). The policy framework enables a coarse (strategic) level of reserve planning to start with and a refined (detailed) level by March 2014. This commitment to spatially locate targets is especially important to the environmental sector as forest retention targets are often set, but remain aspatial, making it difficult to track change, especially regarding amounts of different species habitats.

A myriad of forest planning and practices regulations in the Forest and Range Practices Act and Ministerial Orders apply to forest land owned by the province (public forest tenures). The Act sets objectives for 11 key forest and environmental values including biodiversity, cultural heritage, forage, recreation, resource features, riparian/fish, soils, timber, visual quality, water and wildlife. Simpler regulations apply to some private land designated as managed forest land and minimal regulations apply to the remaining private forest land. Specific regulations in the Land Act legalise aspects of land-use plans (Land and Resource Management Plans).

The regulations include specific habitat protection for ‘identified wildlife’ – 70 species and 15 plant communities. Species identified as being negatively affected by forestry or range practices – ‘species at risk’- by the Committee on the Status of Endangered Wildlife in Canada (table 3) are listed under the Forest and Range Practices Act (Erickson et al., 2007). The species are grouped into listed elements – species, species-pairs, subspecies, populations, population units, or plant communities – and species accounts and measures address their habitat requirements. We were interested to learn, however, that under current government policy the timber-supply impact of the objectives for identified wildlife in the Forest and Range Practices Act may not exceed 1% of the short-term timber supply by forest district. However, we were advised that government may reconsider this 1% threshold if it does not deliver objectives for managing species at risk.

Table 3 Examples of species at risk in B.C. (established under the Forest and Range Practices Act by provincial order May 6, 2004, from Erickson *et al*., 2007). Note that several of these species (marked #) are represented in Canada by marginal northward extensions of range from USA, where they are much more widespread and not necessarily threatened.

Fish
Gasterosteus sp. 16
Gasterosteus sp. 17
Vananda Lake Limnetic Stickleback
Vananda Lake Benthic Stickleback
Birds
burrowing owl *Athene cunicularia #*
Lewis's woodpecker *Melanerpes lewis #*
marbled murrelet *Brachyramphus marmoratus*
'Queen Charlotte' goshawk *Accipiter gentilis laingi*
white-headed woodpecker *Picoides albolarvatus #*
yellow-breasted chat *Icteria virens #*
ancient murrelet *Synthliboramphus antiquus*
flammulated owl *Otus flammeolus #*
great blue heron *Ardea herodias fannini #*
long-billed curlew *Numenius americanus #*
sage thrasher *Oreoscoptes montanus*
northern spotted owl *Strix occidentalis #*
short-eared owl *Asio flammeus*
'interior' western screech-Owl *Megascops kennicottii #*
Reptiles
'Great Basin' gopher snake *Pituophis catenifer deserticola #*
Amphibians
tiger salamander *Ambystoma tigrinum #*
coastal giant salamander *Dicamptodon idahoensis #*

coeur d'Alene salamander *Plethodon*
Rocky Mountain tailed frog *Ascaphus tenebrosus*
northern leopard frog *Rana pipiens*
coastal tailed frog *Ascaphus truei*
Mammals
Pacific water shrew *Sorex bendirii #*
Keen's long-eared myotis *Myotis keenii*
fringed myotis *Myotis thysanodes #*
spotted bat *Euderma maculatum #*
Vancouver island marmot *Marmota vancouverensis*
badger *Taxidea taxus jeffersonii*
wolverine (2 subspecies) *Gulo gulo luscus & G.g. vancouverensis*
caribou (3 populations - mountain, boreal and northern) *Rangifer tarandus caribou*
grizzly bear *Ursus arctos*
Plants
tall bugbane *Cimicifuga elata*
Scouler's corydalis *Corydalis scouleri*

3.2.2.2 Certification systems

Canada has more voluntarily certified forests than any other country with about 140 million hectares certified across the country and 50 million hectares of certified forest in British Columbia. The Canadian Standard Association (CSA) certification system has now been adopted by most private companies and other certification systems are also used. CSA and other certification systems all have an emphasis on the conservation of biodiversity (indicator 1), so companies generally manage to meet the standards of international certification. In comparison we learnt that the US certification system (SFI) has limited relevance, simply because many American mills run on 'gate wood' and don't know where the wood came from, hence land management is not considered (F Bunnell, pers. comm.). Although government regulations are minimal on private land, the companies still have to compete for market share, so are generally certified to international standards.

3.2.2.3 Forestry planning

A hierarchy of planning processes are part of the system to manage biodiversity in British Columbia public forests. The regional plans (e.g. Bulkley Land and Resource Management Plan, Interagency Planning Team, 1998) provide the broad landscape-scale goals and zoning for biodiversity emphasis.

On public forest tenures the Forest and Range Practices Act requires two levels of plans – the forest stewardship plan and the site plans. The forest stewardship plan is prepared by the licensee and submitted for approval by the government. Other requirements include consultation with First Nations and providing an opportunity for review and comment by the public and other resource users. The forest stewardship plan identifies forest development units within which forestry activity can occur, and must provide measurable results or verifiable strategies consistent with government objectives for various forest values. They must also comply with the broad goals and land-use zoning for management intensity and biodiversity in the regional land-use plans (e.g. Vancouver Island Land Use Plan) (Beese and Deal, 2010). Forest stewardship plans have a five-year term that may be extended to 10 years. Any deviations from the minimum government practice requirements must be justified and approved.

Tenure holders must also prepare site plans that identify intended roads, coupes (cutblocks) and forest stewardship plan strategies or actions for the site. The site plans are not approved by government but must be available to the public on request (Beese and Deal, 2010, Ministry of Forests and Range, 2006).

3.2.3 Development of objectives and management strategies

The Forest and Range Practices Act /Land Act government framework follows a multi-species, multi-spatial scale approach to conserving biodiversity in British Columbia's forests. Objectives that come under the Land Act aim to guide conservation of biodiversity at the landscape-scale (e.g. old-growth order). The Forest and Range Practices Act regulations include a mix of landscape- and stand-level objectives and minimum practice requirements for biodiversity (appendix C). The Forest and Range Practices Act sets out the major forest values that managers are expected to maintain or enhance on public lands. Objectives that need to be taken into account by the industry include those in regional land-use plans (e.g. Vancouver land-use plan).

Many of the current government objectives and provisions for biodiversity delivered via the Forest and Range Practices Act /Land Act framework appear to have evolved from those in the previous *Forest Practices Code of British Columbia*. There are a number of ministries (e.g. Ministry of Forest and Range, Ministry of the Environment) involved in the ongoing development of these objectives. In general the objectives are very broad and the detail of the desired outcome – what they intend to achieve- isn't clear (see appendix C). Although there are specific practice requirements for some biodiversity values, it is up to the licensee/industry/company to work out what to do to meet objectives for most values. Licensees may propose an alternative to any practice requirement in the regulations providing it is consistent with the Forest and Range Practices Act objectives. For example, under the Forest and Range Practices Act, the regulation sets out practice requirements for riparian areas but licensees may propose alternative results and strategies in their forest stewardship plans provided the alternative is consistent with the Forest and Range Practices Act broad goals/objectives for water, fish, wildlife and biodiversity within riparian areas. Our impression was that the most common regulatory failing was related to utilisation standards and the amount of woody debris left for biodiversity. Riparian practices around small headwater streams were also considered an issue by some scientists.

There did not appear to be a clear efficient process for the development of objectives at the provincial-level. Although the government emphasises public involvement to ensure consideration of social values there seemed to be a problem with the degree of industry involvement in some cases. As one researcher put it – '*the biggest problems have arisen when civil servants, long out of practice, huddle around desks and create something that makes sense only to civil servants. Industry does get to comment on what is theoretically draft, but there often isn't a heap of trust and draft becomes reality.*' A number of government scientists and policy makers that we spoke to noted that the government was aware of this governance issue and increased communication with licensees and professionals was planned as part of future work.

Landscape-level objectives and threshold-levels delivered via the regional land-use plans include a myriad of objectives. The overriding principle – 'ecosystem-based management (EBM)' – is defined as 'an adaptive, systematic approach to managing human activities that seeks to ensure the co-existence of healthy, fully functioning ecosystems and human communities'. EBM has two sub-goals

– ecological integrity and human well-being – each with objectives and strategies at different scales. Agreements with First Nations and information from reviews by various assessment teams (e.g. Coast Information Team and later EBM Working Group) are used to inform the development of these objectives. We learnt that there is some tension between what has been specifically 'approved' as part of this process by the provincial government and what is 'background information'. Usually, what government has 'approved' is clearly stated or referenced in its public news releases (L Williams pers.comm.).

The certification systems also provide a framework of goals and objectives. How these objectives are developed by the certification systems was not explored as part of this review but was described as a 'zoo' by one researcher. Some certification systems (e.g. CSA) require the industry companies to develop indicators to be monitored in conjunction with a local community advisory group. We learnt that companies have to juggle the objectives of the certification system they are seeking and the provincial regulations in the Forest and Range Practices Act and Land Act. In general, they find ways to merge them but occasionally there are outcomes that conflict. One interesting example of this is involved the decision made by MacMillan Bloedel in the late 90s to adopt a new form of forestry, variable retention, for harvest operations in coastal British Columbia (reported in Bunnell and Dunsworth, 2009). The main driver for this change was the effective market campaigns to stop clear-cutting of old-growth and the subsequent impacts on the company's ability to gain certification. When variable retention was first introduced however it was it was 'illegal' because all the laws addressed clearcutting – there were no regulations to describe or guide variable retention. Government personnel reviewed the ecological rationale and met with the project team members to develop regulatory systems (Bunnell and Dunsworth, 2009). Interim, simple but effective guidelines and training programs were developed to enable the company to phase in variable retention before all the legal standards were finalised. An Adaptive Management Working Group was formed as part of this project. Their role was to work with government agencies to create a way in which novel practices, not encompassed by current regulations, could proceed (Bunnell and Dunsworth, 2009; Bunnell and Beese pers.comm.).

Professor Bunnell, who works with private companies to develop goals and objectives as part monitoring required for certification, told us that the first step in the process involves workshops to extract the critical questions and rank them. Examples of the broad criterion and indicators used are provided in table 4. Sub-indicators are then developed.

Table 4 Example of criterion and indicators used in some monitoring programs required for certification.

Criterion	Biological diversity (native species richness and its associated values) is sustained within the tenure.
Indicator 1	Ecologically distinct ecosystem types are represented in the non-harvestable land base of the tenure to maintain lesser known species and ecological functions.
Indicator 2	The amount, distribution and heterogeneity of stand and forest structures important to sustain native species richness are maintained over time.
Indicator 3	The abundance, distribution and reproductive success of native species are not substantially reduced by forest practices.

The province supports forestry related research that informs the development of objectives through the Forest Science Program which is part of the Forest Investment Account (a line item in the Ministry of Forests and Range budget). The total spent on the entire program (with biodiversity as a sub-program) over five years (2004–09) was $34 million (approximately $6.8 million a year) (M. Eng pers. comm.).

Management strategies

On public land, management actions for biodiversity include landscape-level actions required in land-use plans (e.g. Interagency Planning Team, 1998). In these plans the management actions to meet the 'ecological integrity' objectives include a zoning system with various levels of protection and legal orders that define different levels of forest management based on high/medium and low risk to biodiversity. They may include the requirement to meet a threshold-level. These are developed using information on the range of natural variation and aim for representative reservation. This can sometimes be met through restoration of a particular area. Threshold-levels are developed using models of the range of natural variation (L. Williams, pers.comm.). A handbook has been developed to provide the overriding 'ecosystem based management' (EBM) planning framework. It was developed by the first assessment team (i.e. Coast Information Team) and was accepted by government as 'guidance' for 'ecosystem based management' implementation (Coast Information Team, 2004).

Areas retained in public forest include old-growth management areas (for ecosystem representation in larger patches), riparian reserve zones (buffer widths vary by stream or wetland class), wildlife habitat areas (species specific reserves, including those required for 'species at risk'), ungulate winter range (deer, elk, goat), rare plant and ecosystem reserves (Beese and Deal, 2010). Stand-level actions include the requirements for the retention of wildlife tree (Wildlife Tree Retention Areas) and other wildlife habitat features such as specific raptor nest trees, buffers and bear dens. Identifying a wildlife habitat feature triggers a practice requirement that should aim to ensure that operational activities do not damage or render ineffective a wildlife habitat feature (Konkin, Macatee and Trumpy, 2005).

A variety of management actions are also implemented to meet the Forest and Range Practices Act's requirements for seral stage distribution, patch size (maximum clearcut size), landscape connectivity and coarse woody debris. There is an emphasis on the need to maintain heterogeneity of age structures across the landscape rather than an emphasis on floristic communities.

Management actions for 'species at risk' are applied in areas where the government has identified the presence of the species or its habitat. It is up to the licensee to prepare a forest stewardship plan consistent with the broad Forest and Range Practices Act objective for a particular species, i.e. to conserve sufficient wildlife habitat in terms of the amount, distribution and attributes of areas of habitat for the survival of the species. Any actions, however, also need to be consistent with the objective of not unduly reducing the supply of timber from British Columbia's forests (Konkin, Macatee and Trumpy, 2005).

As mentioned above often it is up to the licensee/industry/company to work out what to do to meet objectives for most values. Licensees may propose an alternative to any practice requirement in the regulations providing it is consistent with the overarching objectives in regulation. The forest stewardship plans developed by the companies must describe how the Forest and Range Practices Act values are maintained and these must be justified and approved. The certification systems also require the company to develop strategies to meet the framework of goals and objectives required by the system in conjunction with a local community advisory group. The effectiveness of these strategies for each forest area covered by the certification (Defined Forest Area) must then be monitored using agreed indicators.

3.2.4 Approaches to effectiveness monitoring

Although there is no requirement for monitoring under the Forest and Range Practices Act, effectiveness monitoring appeared to be a hot topic in British Columbia. From what we could gather this was because monitoring programs in British Columbia are predominantly driven by market-based requirements. That is, the need to demonstrate a commitment to forest stewardship (social licence to operate) and continual improvement (certification requirement). We did not learn about any federal monitoring initiatives during our visit.

3.2.4.1 Forest and Range Evaluation Program (FREP)

In 2003, the government initiated an ambitious Forest and Range Practices Act Resource Evaluation Program (FREP) (Paige and Darling, 2009). The program is a multi-agency initiative led by the Ministry of Forests and Range. The aim is to evaluate the effectiveness of the Forest and Range Practices Act objectives, strategies, results and practices in maintaining and conserving resource values, including biodiversity, on public land throughout the province. The idea is that over time these evaluations will enable government to determine whether or not the Forest and Range Practices Act's provisions are scientifically sound and effective in conserving biodiversity. Both the objectives and the actions are being evaluated.

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 and Darling, 2009). The effectiveness evaluations carried out under the program may incorporate trend monitoring (baseline or status) and implementation monitoring (table 1). The program recognises the importance of monitoring implementation or compliance in interpretation of the results obtained from an effectiveness monitoring project. Projects to gather knowledge and to validate basic assumptions may also be carried out under the program to complement the effectiveness monitoring (Paige and 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.

Principles have been developed to guide the effectiveness monitoring. These include the involvement of industry professionals in priority-setting and project design and implementation, with government co-ordination around the province and a centralised database and data analysis (Paige and Darling, 2009).

The first phase in the FREP program is to develop measurable objectives and questions for the eleven key environmental values covered by the Act. These are then used to determine whether or not management strategies for a particular value are meeting their intended goals and objectives. The question are developed by Resource Values Teams that include representatives of the forest industry and the government (Paige and Darling, 2009). Determination of FREP priorities for monitoring are based upon perceived level of risk. For example, questions relating to streams where riparian buffers are not specifically required are a high priority for evaluation (McMillan and Warttig, 2007). 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 and Darling, 2009).

The second phase is the identification of appropriate indicators and thresholds to address the monitoring questions. An example of a monitoring question is - 'do wildlife habitat areas provide habitat features to meet the life history requirements of the Great Basin gopher snake?' The indicators used to answer this question include habitat feature disturbance, vegetation condition and shelter and egg-laying habitat availability (Erickson, 2007). The indicators are selected taking into account the following considerations (McMillan and Warttig, 2007) -

- Focused on answering a specific evaluation question;
- Correlated to what you want to measure;
- Based on valid scientific research and literature;
- Relevant at various scales (site, feature, landscape);
- Responsive to forest and range practices in a predictable way;
- Low naturally occurring variability;
- Well documented (rationale, methodology, analysis);
- Peer reviewed;
- Understood and supported by stakeholders;
- Practical, easy to measure, interpretable;
- Cost effective;
- Comparable to existing baseline data; and
- Part of a suite of indicators for evaluating a resource value

The third phase in the FREP program involves project design and implementation – development of protocols, pilot projects, collection and analysis of data. The on-the-ground implementation of the program itself is done at the district- and regional-level, generally by agency (Ministry of Forestry and Ministry of the Environment) staff. The technical team results and recommendations are reviewed by the Resource Value Teams (Paige and Darling, 2009).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 and Smith, 2009), a toolbox for forest managers, articles in newsletters and 'continuous improvement' meetings with industry.

Our impression from our meeting discussion with the scientists involved with FREP was that although a lot of work had been carried out on the first phase of the evaluation procedure, with heavy emphasis on the development of protocols, there were few results to date. Much of the program seemed to be in the early stages. Out of the resource value areas the biodiversity and riparian sub-programs appeared to be the most well-developed from a protocol and implementation perspective (British Columbia Ministry of Forests. 2005; Tschaplinski, 2009). However, in both areas (biodiversity and riparian) the definition of 'effectiveness' is used loosely, mainly because what is trying to be achieved is not well defined. There was a focus on monitoring habitat surrogates rather than biological response and a focus on stand-level indicators. However, we did learn that catchment-scale indicators are being developed (P. Tchaplin pers.comm.).

The wildlife area appeared to be the least 'developed' of the program areas, as the focus has been on measuring biological response to management at a range of scales as well as structural and compositional results of management. This area looks at the effectiveness of species specific management measures such as the wildlife habitat areas (WHAs) and ungulate winter ranges (Erickson et al, 2007; Kinley, 2009). Questions being explored include ones at the stand-level such as to what degree do the WHAs maintain suitable habitat conditions to meet the requirement of the target species (at the landscape- or species' range-scale) and how much suitable habitat occurs within the range of the target species? In order for such questions to be answered, there is a need to establish the relationship between species and habitats and we learnt that this research is part of the government Forest Science Program. Future work aims to focus on landscape-scale monitoring of wildlife involving the development of landscape-scale indicators. For example, a study has been initiated to examine the role of WHAs in the conservation of the Great Basin gopher snake and the Rocky Mountain tailed frog across all land tenures (Erickson et al., 2007).

A key issue raised by the scientists involved in the FREP program for the future success of FREP was the security of funding and resourcing. The initial funding for the project was in the order of $4 million per annum. We learnt, however, of recent resourcing issues with staff cutbacks which was cause for some concern. Fragmentation of research groups and lack of consistent access to inventory data and species data was also considered an issue. A future challenge is the need to demonstrate the value of the program. Plans include increased communication with industry professionals, providing an 'improvement plan' on the web each year and modification of indicators to take into account climate change.

3.2.4.2 Effectiveness monitoring by private companies

As well as the initiation and development of the government FREP program, we learnt about some very successful private effectiveness monitoring initiatives. One of these was initiated by the MacMillan Bloedel company in collaboration with academics at the University of British Columbia (Bunnell and Dunsworth, 2009; Beese and Deal, 2010). The main motivator of this monitoring work initiated by MacMillan Bloedel was public protest in response to the forest harvesting in the Clayoquot Sound area of Vancouver Island which peaked in1995 (McMillan and Warttig, 2007). The company asked – 'how can we operate as a forestry company whilst also keeping people happy?'

The project MacMillan Bloedel initiated (subsequently continued by Weyerhaeuser and Western Forest Products Inc.) aimed to look at the effectiveness of a strategy developed for biodiversity conservation (the Coast Forest Strategy, now known as the Western Forest Strategy, WFS) (Bunnell and Dunsworth, 2009; Beese and Deal, 2010). Ecologists, silviculturalists, growth and yield modellers, harvesting practitioners, economists and social scientists worked together to develop the mixture of studies required. There was an annual review of the overall project by an independent science panel. We learnt, however, that in recent years funding issues have meant that the science panel hasn't met for a while.

The overarching goals of the WFS are: to represent the full range of ecosystems within the non-harvestable land-base to maintain lesser known species and ecological functions; to maintain structural attributes of older forests distributed across the landscape and in harvest areas to support biological richness; and to sustain productive populations of forest-dwelling species over time. The project monitors a number of indicators relevant to these goals. 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, the amount and characteristics of stand structural elements, such as snags, that are retained after harvest are assessed. 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, however permanent ground based transects are also used.

Forest-dwelling species, selected based on their sensitivity to forest practices, ease of monitoring, and utility of information to guide management, are also monitored (Kremsater et al., 2003; Beese et al. 2005; Bunnell and Dunsworth, 2009; Beese and Deal, 2009). The program uses a multi-species approach for two reasons. We learnt that the reasons for this are that the government funded Recovery Teams monitor single species 'at risk' and secondly many certification processes include Public Advisory Committees that want to know about all species. We were told that the issue for industry is to cooperate with or at least not hinder the single-species approaches while getting on with what the public wants. Canadian Forest Products and university scientists are currently developing a 'species accounting system' that groups species into categories according to different monitoring needs (those that require field studies and those that can be monitored by monitoring habitat) (Beese and Deal, 2010).

Sites are established across the landscape covered by the strategy in harvested and unharvested areas using a replicated, experimental design. The program includes monitoring of operational sites/coupes (Figure 11) across the land tenure covered by the strategy (Bunnell and Dunsworth 2009). A grid-based approach was not adopted because of the need to sample operational blocks (areas where the particular action is implemented), the difficulty in developing a cost-effective grid-based approach for a variety of species and the varied terrain in the plan area (Beese and Deal, 2009).

The project has been running for 12 years and has ongoing support from company managers, community groups and government regulators. A community advisory group, established as part of certification requirements, provides regular feedback and suggestions and environmental NGOs were involved in organising the science panel reviews. The results of the project are communicated through annual reports, extension material and project reports. The program is estimated at $400–500k per year, but we were told that the company regards this as the cost of doing business and gaining certification.

Figure 11 the Montaine Alternative Silvicultural System project site. (Photo: S Munks)

Prior to 90s, clearcutting was the main silvicultural system in British Columbia forests. A decision was made by a private company, MacMillan Bloedel, to try smaller harvest units to get better regeneration in higher elevation forest. The Montaine Alternative Silvicultural System (MASS) pilot study was set up to investigate variable retention method (similar to green retention method driven by Jerry Franklin in Oregon and Washington). Sites were established in old-growth alpine western red cedar, western hemlock, Douglas fir and amabilis fir forest (800–1500 years old). The study has monitored the response of species and regeneration. The best outcome was achieved where small patch cuts were applied (1.5–2ha). Variable retention was applied in all forest managed by MacMillan Bloedel.

Other private initiatives we learnt about were projects carried out by the biologist working for another private company, International Forest Products (e.g. Poulin and Warttig, 2005; Muir and Warttig, 2010). One interesting project involved monitoring the effectiveness of actions taken to restore fish habitat affected by steep-slope logging and removal of timber from stream edges (Poulin and Warttig, 2005). The results provide useful information to inform future restoration projects. International Forest Products spends approximately $2–300 000 on monitoring programs and contribute to monitoring projects by students.

3.2.4.3 Monitoring of land-use plans

Monitoring programs looking at the effectiveness of land-use plans were in the early stages. Those involved were grappling with how to monitor a mix of ecological risk and socio-economic risk. An Adaptive Management Steering Committee was set up to oversee the monitoring of plans developed using EBM principles. The committee is charged with developing a monitoring regime to look at change over time. More specifically the monitoring regime is required to look at affect of land orders on the environmental and socio-economic values indicators. The committee had been working for nine months at the time of our visit and had just got to the stage of discussing draft indicators and methods for prioritizing objectives and associated projects. Future work is planned as a collaborative effort between the Uiversity of British Columbia and government scientists. The current focus is on monitoring the implementation of the plans actions. Remote sensing will be used as much as possible and site-level assessments are planned to occur in collaboration with foresters and NGOs (e.g. Nature Conservancy Canada). Funding includes $600 000 in grant funds for the adaptive management steering committee.

For some land-use plans, monitoring is not just a stage in the adaptive management process but has also been driven by the need to resolve conflicting views on the effects of plans on the environment. Attempts to resolve such conflict led to the establishment of the Babine Watershed Monitoring Trust, based in Smithers in 2005 (Overstall, 2008). The role of the trust is to conduct impartial monitoring of the effectiveness of land-use plans that cover the Babine River drainage (Bulkley Valley Community Resource Board, 1998). This forested catchment covers about 400 000ha and it has a high economic value for the timber industry. There is a high grizzly bear population in the catchment and grizzly/human impacts are one of the issues. The river catchment is also very important to the fishing industry.

The trust was chosen as the only governance structure that would allow diverse and conflicting interests to participate in monitoring of land-use plans, such that no one interest could control the results (Overstall, 2008). The trust includes representatives from all stakeholder groups (e.g. anglers, tourism operators, forest industry and government agencies). Ecological consultants designed a novel method by which monitoring priority is determined using probability of success and uncertainty, and the importance of an objective (Price and Daust, 2009). An important element is a review of existing knowledge that is transparent and easily updated and communicated. The trust identifies the actions found to be most likely to not meet the plan objectives and then initiates projects to evaluate the effectiveness of the actions. The approach avoids wasting valuable resources on projects that are not going to deliver useful results for management. Projects selected for funding covered all types of monitoring (implementation, effectiveness and validation). They also use a variety of methods, including retrospective studies.

The Babine example highlighted to us the importance of applying good governance principles in any decision-making process and of having rules that determine what and how to monitor and use the results to inform management. Many of the organisations we visited had spent a lot of time grappling with what to monitor and how to monitor and the decision-making framework used by the Babine Trust could have wider applications. The trust has been running for five years at a cost of approx $50 000 a year. Current funding is primarily from both government and industry (mainly tourism), although government funding has recently declined. The trust is a registered charity so it can apply for funding which is often out of the reach of government departments.

3.2.4.4 Forest Practices Board

The Forest Practices Board, based in Victoria in British Columbia, acts as an independent watchdog. It conducts monitoring of compliance with the Forest and Range Practices Act and investigates public complaints and reports to public. It also conducts some special projects which are useful in interpretation of the results obtained from effectiveness monitoring projects (Forest Practices Board, 2004; Forest Practices Board, 2009). One study found that the provincial government's biodiversity strategy under the *Forest Practices Code* is applied unevenly across the province, and key on-the-ground measures are not being implemented in many areas (Forest Practices Board, 2004). The work of the board has highlighted a need for effectiveness monitoring to be required under legislation. If there is flexibility in a system then it needs to be monitored to see if it is working.

3.2.5 Adapting management

The FREP has a clear process by which the outcomes of projects are reported (Paige and Darling, 2009; Snetsinger, 2009). However the process by which decisions are made to adapt management was unclear. We learnt that the results from the biodiversity and riparian sub-programs have been used to inform management. For example, in the biodiversity area three key practices (i.e. retaining more long coarse woody debris, retaining higher densities of large trees, leaving larger retention patches) have been recommended to improve biodiversity outcomes (Snetsinger, 2009). These outcomes are provided as considerations for improved forest and range stewardship under the Forest and Range Practices Act via an annual Chief Foresters report (Snetsinger, 2009). This report states that '*In keeping with the results-based approach, these considerations are neither directive nor prescriptive.*

Front-line forest and range professionals are best positioned to develop site-specific, innovative, local, and cost-effective solutions for the stewardship of our public forests and rangelands.

The WFS, initiated by the private company MacMillan Bloedel, includes a process for feedback to management to enable revision of the strategy based on results of monitoring and research (Beese and Deal, 2009). In the twelve years that the project has been running, the outcomes of the monitoring work have been used to adapt management in a number of ways, including the replacement of clearcutting with variable retention to improve biodiversity outcomes (Beese and Deal, 2009; Bunnell and Dunsworth, 2009). We learnt that other private companies also changed their forest management plans on the basis of the outcomes of monitoring provided it does not cost them greatly. Chasing market share helps.

The Babine Watershed Monitoring Trust has been in operation for five years and produces project reports with recommendations about updating existing land-use plan objectives and strategies. These are provided to a community resource board which includes representatives from the provincial government. This board then makes a decision on what needs to be changed in the land-use plan. The BMWT role is as a knowledge broker it has no legal mandate to enforce anything and the requirement for its existence is not yet established in legislation. The success of this process depends very much on champions – people who support innovation. Since the approach has only been running for five years there were few examples of the monitoring resulting in changes to policy. The examples we did learn about included a change to stream management resulting from a study of sedimentation to streams and a change to target levels of old seral forest to maintain natural seral stage distribution (Price and Daust, 2009). The Babine experience also highlighted the fact that most examples of adaptive management cycles miss the political decision-making cycle where socio-economic preferences are translated into plan or policy outcomes.

3.2.6 Strengths and Weaknesses

Biodiversity conservation management in British Columbia delivered by the Forest and Range Practices Act and the Land Act framework takes a coarse-filter fine-filter approach, with both landscape- and stand-level measures. The move, in 2005, to a results-based system with reliance on the forest manager to make the decision on actions to meet objectives in regulations, has resulted in more flexibility than the previous prescriptive code. However, although the government insists that the outcomes for biodiversity are similar under this approach this is as yet unknown. Some feel that it will result in a poor outcome with overall lower standards and the potential for variable standards in forestry practices across the landscape. Effectiveness monitoring, monitoring of practices and a commitment to adaptive management is essential if such a results-based system is to work and remain acceptable to the broader community. Land-use plans at the regional-level through EBM principles are a good initiative, with the potential to result in good environmental outcomes. However, they are hampered by the need to meet conflicting objectives for 'human wellbeing' and the environment. There is also a need for ongoing monitoring of the effectiveness of this planning process and the outcomes it delivers.

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 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 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 FREP program. Another weakness was the lack of requirement for monitoring in Forest and Range Practices Act. Lack of inclusion in legislation and insecurity in funding suggests lack of commitment by government. Currently monitoring appears to be mainly driven by need for 'social license to operate' – for industry to show practices are meeting goals (e.g. WFS case study).

The FREP program contributes to raising awareness about biodiversity and its management in British Columbia's forests. As a government co-ordinated program, all data and other information that comes out of the projects is available to all – central data storage and availability. In general, we found that FREP was supported by industry as industry certification requires monitoring of effectiveness. Including a broad range of activities in the definition of effectiveness evaluation was identified as a strength, as was the inclusion of local forest managers in priority setting and project design. The focus on species at risk and Forest and Range Practices Act recommended actions could be seen as a weakness but the importance of co-ordinating FREP efforts with broader species monitoring efforts by others was recognised as important by those we spoke to. Such co-ordination is needed to enable comparison with species trends observed in areas without any special protection/management actions thereby providing insights about the contribution of Forest and Range Practices Act in species decline or increase.

The combination of private and government effectiveness monitoring initiatives in British Columbia was interesting and complex and we saw the need for some form of overall co-ordination to ensure continuity. Ownership of companies, and related timber rights, appeared to change fairly often leading to a lack of security for management strategies developed by a particular company in a particular area. We were impressed by the amount of community involvement and efforts to build trust between stakeholders in many of the programs we learnt about. Particularly impressive was the Babine Watershed Trust approach which highlighted the importance of good governance and choosing goals and objectives that are most likely to deliver results in a monitoring study. The Trust has brought a lot of clear thinking about objectives and strategies to achieve them. The long-term security of the Trust, however, depends a lot on the personalities involved and on continuing funding coming in.

There were few examples of effectiveness monitoring leading to adaptations in management. The main reason for this was that most of the programs we visited had only reached the implementation stage. The WFS program, however, was an exception (Beese and Deal, 2010).

3.3 Alberta

3.3.1 Forestry context

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). Alberta harvests 30 million m^3 wood annually, of which 18.4 million m^3 is coniferous and 11.6 million m^3 is deciduous (Government of Alberta, Highlights of the Alberta Economy, 2009). Alberta is a strongly resource-based economy, with oil and gas extraction comprising more than 30% of GDP; agriculture, including forestry, contributes about 2% to GDP. The population of Alberta is 3.7 million people.

There are five main eco-regions in Alberta (mountains, foothills, boreal, parkland and prairies), four of which are dominated by forests (Figure 13). Most of the northern half of the province is boreal forest, while the Rocky Mountains along the south-west border with British Columbia are also largely forested. The south-eastern quarter of the province is prairie (grasslands), with the central, aspen parklands region occurring between the prairies and the forests. Alberta has a dry, continental climate with average winter (January) temperatures of -8^{o}C in the south and -24^{o}C in the north and average summer (July) temperatures of 24^{o}C in the south and 16^{o}C in the north. The rain shadow from the Rocky Mountains extends over most of Alberta with annual precipitation ranging from 300 mm in the south-east to 450 mm in the north, except in the foothills of the mountains which receive approximately 600 mm annually.

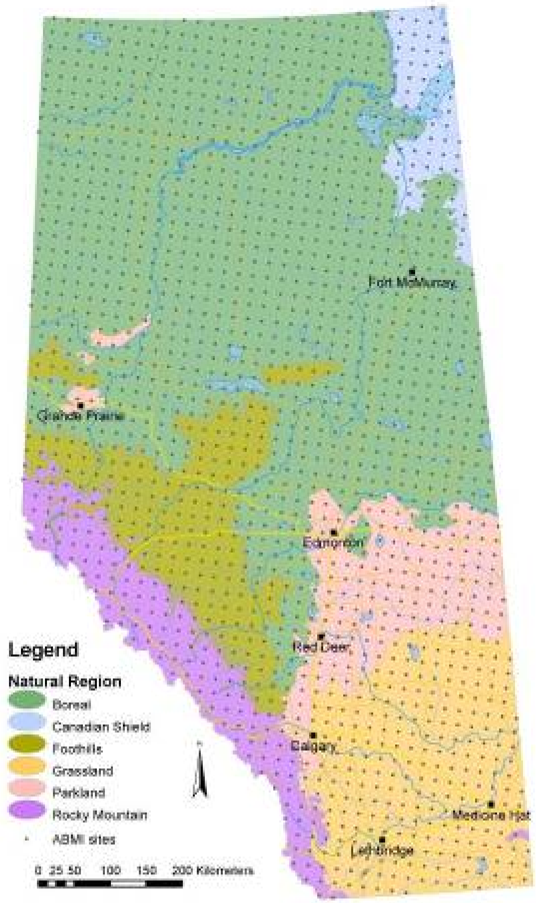

Figure 13. Location of Alberta Biodiversity Monitoring Program sites, and the main cities and eco-regions in Alberta (www.abmi.ca).

Most of the land in Alberta is publicly owned (approximately 60% by the Government of Alberta and 12% by the Government of Canada), with only about 28% in private ownership. Alberta has five National Parks managed by Parks Canada (Banff NP, Waterton Lakes NP, Jasper NP, Elk Island NP and Wood Buffalo NP) and numerous provincial parks and reserves managed by the Alberta Ministry of Tourism, Parks and Recreation. The total protected area in conservation reserves throughout Alberta is approximately 9 million ha (13.6% of the province). However, less than 8% of boreal forest in the province is protected from development, with more than 50% allocated for logging.

The Alberta Department of Sustainable Resource Development is responsible for managing forestry operations in the province and this is achieved primarily through a range of forest tenure agreements with private industry. These arrangements include:

- timber permits, for specified volumes of timber (30 days–2 years)
- timber quotas, where the department is responsible for most of the planning for a particular area but companies are given the right to harvest a percentage of the annual allowable cut for the area
- forest management agreements, which are area-based, renewable (for 20 years, revised every 10 years) agreements between the province and a company.

These forest management agreements are the most common forestry tenure arrangements in Alberta and, under this system, companies are responsible for public consultation, management planning and operational matters while the department is responsible for setting standards, approving plans and determining the annual allowable cut for the area.

Alberta currently has 20 forest management agreements (including three joint FMAs). The largest is 5 812 000 ha (Alberta–Pacific Forest Products Inc.) and the smallest is 58 500 ha.

3.3.2 Legislation and policies for biodiversity conservation

Wood production and off-reserve conservation of forest biodiversity in Alberta is regulated by the *Forestry Act 2000* through a range of area-based and volume-based forest tenures (see above) while land and resource ownership is retained by the Crown (province). The Alberta Forest Management Planning Standard (2006) is the standard for preparing and implementing forest management plans (FMP) in Alberta. This standard is based on and extends the Canadian Standard CSA Z809-02 (2002) which is one form of certification of sustainable forest management used in Canada. The Alberta Forest Management Planning Standard is designed to allow a flexible and innovative approach to forest management by forest companies.

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. Higher-level ‘strategic land-use plans’ are prepared from time to time by the Government of Alberta as regional sustainable development strategies to integrate competing resource uses across industry sectors (including oil and gas, agriculture and urban development), as well as conservation or reserve requirements, and FMPs must be aligned with these land-use plans.

FMPs are normally prepared by industry and approved by government. The plans rely on the competence and professionalism of regulated forestry professionals to apply sound forestry principles and practices. Other components of the planning process (see ‘ground rules’ below) include a compartment assessment (where specific compartment-level modification to the FMP is required), a general development plan (similar to an Australian forest compartment plan), a final harvest plan (includes a map) and an annual operating plan (which includes the reforestation program and fire control plan). Regulations associated with the Alberta Forest Management Planning Standard include the Alberta Timber Harvest *Planning and Operating Ground Rules Framework for Renewal* (2008), which sets out the methods used to implement decisions made in the FMP, and the *Partial Harvest (Non-clearcut) Planning and Monitoring Guidelines* (2006), possibly superseded by the above, which outlines departmental expectations for operational stand-level planning including understorey protection during forestry operations.

The ‘ground rules’ address most of the important practical issues involved in operational forest management such as the definition of merchantable trees, watershed protection and buffer sizes, habitat management, species of special management concern, retention of forest structure and woody debris, wildlife corridors, silvicultural methods, soil management, weed, insect and disease protection, road construction, interactions with other forest users, and reporting requirements. For example, part 7 (habitat management) of the ground rules (ATHPOGRFR 2008) describes the manner in which timber operations are to be conducted to maintain biodiversity and ecosystem function in the landscape. These include:

- specification of the placement and width of riparian buffer zones and connecting wildlife corridors
- specifications for determining harvest plan boundaries and the maximum size for cut blocks
- rules about the accumulation, placement and disposal (burning) of logging debris
- rules about the number, size and distribution of retained forest patches within cut blocks
- rules about the protection or avoidance of understorey during harvesting operations and required follow-up assessments

- rules about the protection and avoidance of disturbance to fish-bearing streams and waterways and required follow-up assessments
- detailed rules for the protection of habitat for species of special management concern, including the woodland caribou, grizzly bear, trumpeter swan, and ungulates inhabiting river valley environments
- prescriptions for the management of 'sensitive sites' (e.g. nest, breeding and den sites) for a wide range of species.

Recently, on 18 May 2010, twenty-one member companies of the Forest Products Association of Canada (FPAC), including several operating in Alberta, and nine leading environmental organisations in Canada announced the Canadian Boreal Forest Agreement. This agreement applies to 72 million ha of public forests licensed to FPAC members across Canada. The agreement calls for a suspension of new logging on nearly 29 million ha of boreal forests to conserve significant areas of habitat for the endangered woodland caribou. The benefit to industry is a competitive market edge for participating companies and greater certainty of timber supply due to the suspension of anti-wood campaigns by environmental groups.

3.3.3 Development of objectives and management strategies

Strategic land-use plans are spatially-explicit policy documents in which the objectives are developed from the expectations of society for balancing competing environmental, social, and economic values at the landscape or regional-scale. These 'big issue' objectives are determined through the political process. At the forest management level, the Alberta Forest Management Planning Standard (in its annex 4 on performance standards), sets out the mandatory values, objectives, indicators and targets (VOITs) identified by the Government of Alberta which are to be included in all FMPs as minimum performance standards. This document provides the framework for linking values to clear objectives and measurable indicators and targets. The indicators and targets are less well defined than the values and objectives with the expectation that quantitative targets are developed by the companies in consultation with stakeholders and are rationalised based on social acceptance, sound science, credible analysis techniques, and clearly stated value trade-offs. Guidance is provided to the companies about the process for developing these targets, including the specific forest attributes that need to be taken into account in forest management plans.

Minimum performance standards exist for six criteria, one of which is biological diversity. Three elements of biological diversity are recognised: ecosystem diversity, species diversity and genetic diversity. Within each element, a range of values, objectives and appropriate indicators and targets are identified. For example, within the element ecosystem diversity, value 1.1.1 is 'landscape-scale biodiversity' and objective 1.1.1.1 is to 'maintain biodiversity by retaining the full range of cover types and seral stages'. The suggested indicator is the 'area of old, mature, and young forest in each DFA sub-unit by cover class'. Suggested targets include 'over the 200-year planning horizon; a) gross landbase: greater than X% old forest, greater than Y% mature plus old forest, less than Z% young forest; and b) net landbase: greater than X% old forest, greater than Y% mature plus old forest, less than Z% young forest. Old forest retention shall include the full natural range of ages'. Other biodiversity values include: 1.1.2 'local/stand-scale biodiversity'; 1.2.1 'viable populations of identified plant and animal species'; 1.3.1 'genetic integrity of natural tree populations'; and 1.4.1 'areas with minimal human disturbances within managed landscapes'.

The Alberta Forest Management Planning Standard, with its primary focus on habitat representation and management for the needs of a wide variety of species, is a coarse-filter approach to biodiversity management in production forests. Most of the objectives in each forest management plan are habitat-based, not population-based. The element, species diversity, provides a fine-filter approach by focusing specifically on the habitat requirements (and population parameters, if known) of a limited range of 'high value' species. The *Alberta Timber Harvest Planning and Operating Ground Rules*

Framework for Renewal provides specification and details of the minimum expectations for forest management to conserve biodiversity.

There is scope to improve the setting of appropriate values, objectives, indicators and targets in forest management plans so that they contribute meaningfully to the conservation of biodiversity, but this requires agreement on the desired nature of forests in the future and better understanding of the forest attributes and levels required to maintain a full suite of species (Stadt *et al*. 2006). Scientific research that links a fundamental understanding of forest ecosystems to practical cause-and-effect relationships is therefore crucial for developing objective-based sustainable forest management plans. We learned that the government has recently decided to review the standard to provide stronger direction to companies about forest management planning and about targets and how to meet them. This is happening in response to declining public acceptance of forestry and the need to balance species-level objectives with broader forest management and ecosystem-level objectives. For example, effective management for grizzly bears requires the closure of forest roads to vehicular traffic and to hunters.

3.3.4 Approaches to effectiveness monitoring

The Alberta Forest Management Planning Standard requires reporting on the achievement of all objectives in five-year stewardship reports. At present, the companies do their own monitoring to determine whether targets are achieved for each objective (implementation monitoring). However, this does not indicate whether the targets, and other actions delivered by the forest management plans, are meeting the objectives for biodiversity conservation (effectiveness monitoring). For example, for objective 1.1.1.1, implementation monitoring may confirm that the targets set by the industry (and approved by government) have been met but not whether the targets have been effective in maintaining the full range of cover types and seral stages or whether biodiversity has been maintained. The Alberta Forest Management Planning Standard does not require effectiveness monitoring by the companies. Instead, the Department of Sustainable Resource Development contributes funding ($2–4 million/year) to the Alberta Biodiversity Monitoring Institute (ABMI) (www.abmi.ca), an independent, not-for-profit organisation with board representatives drawn from government, universities, major resource extraction companies, agriculture, forestry and other non-government organisations. This is in implicit recognition of the need for effectiveness monitoring, to undertake regular and systematic sampling of a wide range of land, water and living resources across the province. Forest companies and resource extraction industries in Alberta also 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 Alberta Biodiversity Monitoring Institute (www.abmi.ca) was initiated in 1997–98 as a regional program to monitor changes in forest practices and the responses of forest biodiversity, but was expanded to the provincial-scale in 2003–04 to monitor 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. Funding is provided mainly from government and the big companies involved with natural resource exploitation and use (oil, gas and forestry). The program requires $12 million per year to operate at full capacity but, due to the current economic climate, funding has recently dropped to $5 million per year (J Herbers pers. comm.)

The biodiversity monitoring program administered by ABMI collects data on over 2000 species and habitat features from 1656 evenly-spaced sites (20 km grid) across the province. These sites coincide with those used by the Canadian National Forest Inventory. The data, which are collected from many points using the same methods, permit the integration and generalisation of information across many levels (as information pyramids; Overton *et al*. 2002) to suit a wide range of purposes. The program 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. We learned that three sampling years have been completed so far. ABMI generates reports for different geographic and administrative regions, including forest management agreement areas, that assist companies to track their performance and to report on the status and trends in biodiversity on their tenures.

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.

The Alberta Foothills Research Institute (a semi-autonomous body part funded by government and industry), the Integrated Landscape Management Unit of the Alberta Research Council and the University of Alberta each undertake research on rare and threatened species. The Foothills Research Institute aims to deliver information and tools for sustainable natural resource (particularly forest) landscape management (www.foothillsresearchinstitute.ca). Over the past decade, this institute has produced habitat suitability models for more than 30 vertebrate species, maintained comprehensive research programs and developed planning tools for several high profile species (grizzly bear, woodland caribou, pileated woodpecker, harlequin duck), and investigated ways to improve the management of prescribed burning, stream crossings, fish habitat and watersheds, as well as adaptations to climate change.

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 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, a concurrent and more targeted operational-scale research program would be required to fast-track the evaluation of any new management alternatives.

3.3.5 Adapting management

We didn't learn of any examples of adaptive management, in its classical sense (Walters and Holling 1990), in Alberta. However, as described above, the combination of a clear standard for management planning and operational practice with a broad-scale, trend and cumulative effects monitoring program (ABMI), there is the potential to refine management objectives and biodiversity targets in forest management plans that will lead to improved conservation outcomes. We learnt that the most likely mechanism by which this process can take place is through the 10-yearly revision and renewal of company forest management plans. However, there is also a clear role for research to contribute greater understanding and assessments of the cause-and-effect relationships between species and habitat configurations. For example, forestry operations are known to threaten endangered caribou populations because, while they improve habitat for moose and deer, they also increase numbers of their main predator, the wolf. Caribou populations are very sensitive to wolf predation. Also, management for the grizzly bear requires the de-commissioning of forest roads. Roads through grizzly bear habitat are known to greatly increase the number of road kills of the bears and also to improve access to these areas by hunters (J Stadt, personal communication).

3.3.6 Strengths and weaknesses

Alberta was the only jurisdiction that we visited that had a comprehensive and integrated program of forest management for biodiversity. This program 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 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 data will contribute significantly to improved management objectives and target setting for the forest industry, by reducing uncertainty. However, the weak link at present is the lack of an independent, formal feedback loop to managers and government about the results of detailed monitoring for compliance and the effectiveness of the current objectives and targets for maintaining biodiversity at the stand-level. 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 Planning Standard and Ground Rules for conserving biodiversity.

In common with all monitoring programs that we learnt about, the ABMI program has taken a long time to get established and it is now faced with the ongoing task of demonstrating to government and industry funders that the results it delivers are useful for a wide range of purposes, including evidence to support industry certification and the achievement of biodiversity conservation objectives. The challenge for any biodiversity monitoring program is to maintain its funding for the long-term. This requires high-level commitment and support from both government and industry. So far, ABMI has managed to negotiate this difficult course and has dealt with the risk of fluctuating funds. A strength of ABMI is that it is registered as a charity/not for profit organisation so, as with the BWMT in British Columbia, it can access external funds that are not usually available to government.

4 Discussion

Our study revealed a range of diverse and complex approaches to the management of biodiversity in the different jurisdictions we visited. The diversity and complexity of the approaches were partly a result of the diversity of land ownership, land management governance systems and socio-economic issues. We also found evidence of a general shift away from regulation of forest practices with more emphasis on 'professional reliance' and voluntary certification systems. There have been recent moves toward more ecosystem or landscape based management and more outcome-based management. Probably because of these changes one element of the adaptive management cycle - monitoring - was very popular and as one researcher put it, 'everybody's doing something somewhere!'

Although the details of the legislative and policy framework for biodiversity varied, in general the broad goals were the same. A commonly-stated broad goal of forest management is that biological diversity (i.e. native species richness and its associated values) is maintained or improved across the region or specific area of interest. Three indicators of success in achieving this broad objective are defined by Bunnell and Dunsworth (2009) as follows:

Indicator 1: Ecologically distinct ecosystem types are represented in the non-harvestable land base of the tenure to maintain lesser known species and ecological functions.

Indicator 2: The amount, distribution and heterogeneity of stand and forest structures important to sustain native species richness are maintained over time.

Indicator 3: The abundance, distribution and reproductive success of native species are not substantially reduced by forest practices.

Indicator 1, also known as a 'coarse-filter' approach to biodiversity conservation (i.e. focussing primarily on habitat surrogates), serves to identify unmanaged 'benchmarks'. Indicator 3, also known as a 'fine-filter' approach (i.e. focussing mainly on species), serves to test the Indicators 1 and 2 in terms of their consequences for a range of species.

A coarse-filter, fine-filter approach was evident, to varying degrees, in all four states and Provinces that we visited.

The diversity of approaches to biodiversity management at multiple spatial scales was reflected in a diverse array of monitoring programs with varying links to management. The main features of the five main monitoring programs that we visited are summarised in table 5 and the different monitoring methods used are summarised in table 6. 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) 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).

Table 5 Summary of features of the five main monitoring programs covered in this study tour

Monitoring program (organisation)	Drivers	Scale	$/year and funding source	Type of monitoring*	Start	Feedback to management	Summary of strengths and weaknesses
Northwest Forest Plan monitoring program (NWFP) (US Forest Service)	Northwest Forest Plan (legal directive)	All US National Forests in WA, OR and N. CA	$60 M US federal government	Trend, effectiveness and validation Vegetation cover, extent and condition Watershed and riparian condition Threatened species 'Survey & manage'	< 1994	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	$6 M British Columbia provincial government	Effectiveness monitoring and research. Post-logging assessments of vegetation characteristics, and riparian conditions Multi-taxa and habitat focus	< 2005	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	$400–500 K, industry and grants	Mixture of projects using all monitoring types (apart from trend monitoring) and including research Multi-species, habitat monitoring	~ 1998	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

				Replicated experimental design in harvested and unharvested areas			trends and cumulative impacts
Babine Watershed Monitoring Program (BWMP) (Babine Watershed Monitoring Trust)	Bulkely Valley Land-use plan Industry certification NGO interest	400 000 ha river catchment in the interior of British Columbia.	$50 K provincial government, industry and grants	Effectiveness monitoring projects Vegetation, stand attributes Multi-taxa; population assessments for key species Adaptive management framework	~ 2005	Fairly direct	Excellent governance 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	$5 M AB provincial government and industry	Trend monitoring for cumulative effects Vegetation; multi-taxa (2000 species); human impacts Remote-sensing and extensive ground sampling	< 1998 then in 2003 became state-wide	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 table 6

Table 6 Methods used in the different types of monitoring

Type of Monitoring	**Description**	**Methods**
Baseline, status, surveillance and trend monitoring	Used to acquire information on the condition of a resource value. Usually involves multiple surveys over time or across an area to examine the condition of a particular value. Can help to explain results of effectiveness monitoring program e.g. decline in spotted owl due to increase in barred owl populations.	Repeat measures over time to plot trends and cumulative impacts on the resource, e.g. mean abundance of flora or fauna species. Not necessarily directly related to management. May be regular (e.g. annual) or intermittent. May cover a broad range of species (e.g. plants, birds, mammals) or particular species of interest (e.g. threatened species): different (i.e. research) sampling strategies are needed for rare species. If broad inferences are to be made, the monitoring must be based on a large sample of sites representing the area of interest. NGOs have been very successful in developing broad-based programs for monitoring trends in certain groups of biota, especially birds, in various parts of the world.
Implementation (including compliance) monitoring	Have we done what we said we would do? Records whether or not management actions in plans to meet particular objectives are being applied (e.g. were the required number of hollow-bearing trees retained in a harvest area? Were landscape-level retention targets applied?).	This is often done routinely, either on all logging coupes or on a sample of coupes. Actual implementation needs to be assessed before any predictions of consequences or evaluations of effectiveness can be made.
Effectiveness monitoring (targeted monitoring)	Did our actions achieve our objectives? Used to determine whether the management actions are effective (e.g. are hollow-using fauna maintained in a harvest area with current rates of retention of hollow-bearing trees? Is species diversity maintained across the landscape with current landscape-level retention targets?).	Involves targeted monitoring over time of what happens after a particular type of management (e.g. clear-felling with reserves). If broad inferences are to be made, sites must be well replicated. Usually the aim is to compare alternative management actions and, if so, those alternatives must be monitored too. Sometimes the alternatives are considered as ‘controls’ but we prefer the term ‘benchmark’. For example, useful benchmarks for clear-felling with reserves would be clear-felling without reserves, or no logging at all. Such monitoring may involve retrospective analyses designs (McComb, 2010) involving measurements made at many sites representing different stages in a temporal sequence (‘space-for-time’). Often this approach can be modified to produce useful information for predicting effects of novel management approaches by looking at analogous structures. For example, clear-felling with reserves will produce small patches of mature forest embedded in a sea of regrowth. Such structures

		may have arisen previously in parts of the landscape as a result of fire or windthrow. Studies of flora and fauna in such structures can help predict likely outcomes for flora and fauna into the future. Of course, there are potential traps in this approach (e.g. there may be special features that enabled particular patches to survive previous disturbance, and usually there are no data about the condition of sites before disturbance). The most powerful approach involves retrospective research on sites with historical data, or a combination of retrospective research and judicious monitoring.
Validation monitoring	Investigates the relationship between management actions and objectives (e.g. are hollow-using fauna maintained because of stand-level management actions?). Improves knowledge and has a fuzzy boundary with research. Helps inform uncertainty level.	May be retrospective approach or BACI design. Trend monitoring can also be part of this. Cause-effect establishment.

4.1 Features of effectiveness monitoring programs: lessons learnt from western North America

The monitoring programs we learnt about ranged from small-scale projects, targeting specific questions of current management interest (e.g. Babine Watershed Monitoring Trust projects in British Columbia), to large-scale, well-funded trend-based monitoring, to take into account cumulative effects (e.g. ABMI). The dominant driver for the effectiveness monitoring programs in British Columbia and Alberta was the requirement to demonstrate progress in reporting for wood certification (table 4). In contrast, legislation and national agreements appeared to drive most of the effectiveness monitoring work in Washington State and Oregon. Other reasons for monitoring included: international agreements and, at state or provincial- and federal-levels, the need to demonstrate commitment to forest stewardship (needed for the social licence to operate); climate change monitoring; and relationships with native people.

The programs we visited demonstrated to us that 'monitoring' and 'research' are different, but complementary, with research typically addressing a specific question(s), requiring greater attention to study design, and consequently being capable of providing rapid feedback to managers. Monitoring, however, typically asks few specific questions *a priori*, requires an unbiased, usually systematic sampling design, and establishes a comprehensive platform from which to assess trends in species populations and habitat suitability, as well as determining the cumulative impacts of land management practices. Research, both experimental and retrospective, has an important continuing role to: a) explain why certain trends are happening; b) assist in setting targets for monitoring objectives; and c) assist the development of habitat suitability models for poorly known species (i.e. to provide the basis for expected predictions in monitoring results). As noted by Franklin *et al* (1999) monitoring and research are actually closely related activities which should be tightly linked.

Many of the monitoring programs had taken a long time to get established and, in most cases, the link with management (process to ensure results are used to inform management decisions) was not clear. Adaptive management (i.e. improved management objectives and operational techniques as a result of lessons learned from monitoring) appeared to have been incremental and was difficult to measure. We found few direct examples of monitoring leading to adaptation of management practices. The main exception was the very successful operational-scale program run by the Western Forest Products company (and its predecessors) which resulted in clear changes to management policy and practice, particularly around the acceptance of variable-retention harvesting as a technique for reducing logging impacts on biodiversity. The most convincing evidence of progress towards ecologically sustainable management was the continuing 'social licence' to operate for companies that supported and embraced biodiversity monitoring on their tenures. However, if this 'social licence' is to continue then there needs to be a clear path by which results can be used to inform changes to management practices (Price and Daust, 2009).

As noted by Price and Daust (2009), there has been a focus on learning to monitor, rather than on monitoring to learn. Many were struggling with what to monitor and how to make monitoring manageable. Indeed, all programs required a gestation period of 5–10 years or longer to sort out principles, objectives, sampling designs and methodology, and several were still in the process of developing or fine-tuning their feedback loops to forest managers and the reporting requirements of government and industry. Some programs hadn't got past the implementation monitoring stage (following the traditional three-tiered approach to monitoring), in part because of the additional complexity, but also because of the uncertainty around what the action being monitored is actually able to achieve. However, recent methods developed to provide guidance on the objectives which should be the focus of effectiveness monitoring (e.g. Stadt *et al*. 2006; Price and Daust, 2009) could help with this issue.

The programs we visited illustrate the difficulties that arise when trying to apply a theoretical approach (traditional three-tiered approach to monitoring and adaptive management cycle) to practice.

On the basis of this experience, we identify the following list of considerations that may help in the development and longevity of monitoring programs, which effectively link with management:

- *Good governance is important*

  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). The ideal governance structure appeared to be one in which values are separated from knowledge (e.g. the BWMT and ABMI) and involve those who are implementing the measures – i.e. the industry. The way in which decisions are made can have a direct effect on whether or not decisions are implemented and whether they are successful. More emphasis is needed to ensure good governance of biodiversity monitoring programs and associated decision-making. The characteristics of good governance put forward by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP, 2009) provide a useful guide.

- *Monitoring programs need to deal with funding risk (fluctuations in funding)*

  Longevity in biodiversity monitoring is strongly related to the funding security that follows establishment of the program in legislation and government policy. Monitoring programs are long-term commitments that will fail without adequate commitment, support, and funding provided by government and industry.

  For example, approximately 70% of funding for the ABMI program currently comes from government, with the remainder from industry (table 5). Both the government and industry contributions fluctuate according to the economic climate and there is need to increase the industry component to secure the long-term future of this program. On the other hand, the BWMT program is predominantly funded by industry (mainly tourism) with minimal funding from government. As not-for-profit organisations, both programs can access external funds that are not usually available to government. The BWMT program, however, depends on the contributions and good will of 'volunteer' scientists and is at great risk of collapse without the dedicated involvement of certain key individuals.

  Synergies with other programs (cost sharing and consistency) should be explored to increase effectiveness and efficiency.

- *Clear objectives that reflect the holistic needs of the community are important.*

  Biodiversity monitoring programs were 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). Setting useful objectives is an extremely important task, but far from an easy one. In Washington and Oregon, changes in forest management were driven mainly by legislation, which focused heavily on the needs of threatened species (northern spotted owl and marbled murrelet). Comprehensive monitoring systems are in place for those species, as well as for more holistic elements such as old-growth forest. But there are no monitoring programs to track the fate of wildlife species more broadly in these forests: these matters feature in community expectations and we suggest that gaps of this sort should be avoided. The ideal set of objectives covers a broad range of indicators relating to the ecosystem services provided by forests, that the community wishes to sustain for the benefit of future generations of people and other organisms.

- *The appropriate type of monitoring depends on 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, it can never be a substitute for more specific monitoring and research to address specific questions about 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.

- *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*

  A mix of monitoring types (table 6) and methods (e.g., remote-sensing of vegetation, ground-truthing of stand attributes and species occurrences) is required, depending on the goals of the monitoring program. 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 (called refinement monitoring by Bunnell and Dunsworth (2009) and validation monitoring by Noss and Cooperrider (1994)). This approach may employ either retrospective sites or BACI (i.e. 'research') sites (McComb, 2010). Retrospective sampling is useful where there is a short time frame 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). Implementation monitoring is also a very important pre-requisite to effectiveness monitoring. All types of monitoring are needed to inform adaptive management. The options fit a hierarchy of methods depending on drivers, goals and objectives, priorities, resources, governance structures and institutional competency. A sound institutional framework would help ensure appropriate mixes of different approaches, with intelligent degrees of flexibility.

- *Monitoring projects must address the temporal dimension*

  When we began this tour, we realised that there was a continuum of activities that could be labelled as monitoring, ranging in complexity from the very simple (basic measurements repeated at set intervals over time) to highly complex (research projects endeavouring to understand and model how ecosystems behave over time). The common element is that any monitoring project must concern itself with the temporal dimension. Usually this is taken to involve repeat measurements over time, but we know that retrospective research ('space-for-time') can be used to provide a valuable snap-shot in a much shorter time-frame. However, repeated measures at the same sites are essential for determining trends in forest attributes (e.g. species populations and habitat suitability), as well as the cumulative impacts of management activities, from a pre-determined baseline.

- *Monitoring approaches to be coordinated and complementary*

  The outcomes of our study tour indicated that for monitoring to be effective in any particular jurisdiction, the variety of approaches used needs to be co-ordinated and complementary. One of the most pertinent comments was made to us on our first day by Jerry Franklin, who observed that monitoring systems will often end up as 'fruit salads', containing many ingredients but all together in the same bowl. This is inevitable because different people, groups and organisations will develop or adapt different systems to meet their particular needs. For example, forest management systems need to report periodically about their performance in meeting agreed indicators of sustainability, to a range of different audiences using different criteria. This variety in approaches is arguably desirable but the effects will be most beneficial if they are complementary and part of an overarching co-ordinated approach.

- *Values need to be kept separate from the science when setting objectives and reporting the results of biodiversity monitoring programs*

  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). The ideal structure is one in which values are separated from knowledge (e.g. BWMT and ABMI). It is important for public confidence that there are no suggestions of bias or unreliability in the data collected and reported by biodiversity monitoring programs. An important way to assist this process is to ensure that data are transparent, and regularly posting raw data and/or summaries on a website can help to improve confidence in the system.

- *Prioritise using a ranking method*

  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 and Dunsworth, 2009, Price and Daust, 2009, McComb et al., 2010).

- *Habitat surrogates can be useful but are never the whole story*

  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. There is a vast and growing literature on these subjects. Such models can be powerful tools for improving communication between scientists and managers. Some workers seek the holy grail of strong but simple models linking the needs of particular species to features of the landscape that can be easily monitored by remote sensing, such as various metrics of habitat structure. Occasionally such models are found, but even then the public is rarely convinced that the fate of a species can be monitored adequately just by monitoring the surrogate. This matter has been examined in court on numerous occasions in USA, and verdicts have vacillated unhelpfully between the two positions. Indeed, the case of the northern spotted owl provides a cautionary lesson. Monitoring the extent and distribution of old-growth forests would not have demonstrated the encroachment of barred owls, despite the close dependence of spotted owls on old-growth forests (in the Pacific north-west). An effective monitoring program to help conserve northern spotted owls must include monitoring of the owls themselves. The effectiveness of such a program would be enhanced further if it included a suite of other elements of the biota, to express some of the key ecological processes at work in those forests.

- *Sampling and measurements need to be closely aligned with objectives of user groups*

  Biodiversity monitoring programs are likely to be most effective if sampling and measurements are closely aligned with the objectives, targets and reporting requirements of their principal user groups. Monitoring programs are long-term commitments that will fail without adequate commitment, support, and funding provided by user groups (i.e. government agencies and industry).

- *An agreed process linking monitoring to management decisions is important*

Often when developing an effectiveness monitoring program, the need to establish clear connections to the management decision process is a last step – we would argue that this needs to be given high priority early in the development of a program.

What is missing in many diagrams of the adaptive management cycle is the political decision-making cycle in which socio-economic values, preferences and trade-offs are taken into account in the development of policy (Overstall, 2008). This can be a significant barrier to the link between monitoring and management.

'*There appears to be a near random element in getting change despite attempts to systematise and develop processes to facilitate change. Repeated attempts that have failed prior to final acceptance of change is common. Timing is crucial and it helps to have a champion within and outside the system (Bunnell, pers. comm.).*'

- *Data transparency and importance of communication at all scales with all stakeholders is important*

  Effectiveness monitoring programs need to devote significant resources to data analysis, storage and display (ideally on websites), and to communication and customised reporting of results for government and industry. Data transparency is a key component of the process. There is a need for all to know and understand the science and state of knowledge to facilitate change (McComb, 2010). The messages delivered need to be kept simple to facilitate adaptive management and to reduce procrastination and uncertainty at the manager or policy-maker's desk. One approach is to present information in pyramids of increasing complexity depending on the intended audience (Overton *et al*. 2002).

4.2 Features of an effectiveness monitoring program for the forestry context in Tasmania, NSW and Victoria

Many countries, including Australia, are much less advanced than USA or Canada in their approach to monitoring forest biodiversity and the effectiveness of forest management practices for biodiversity. In some cases it may be possible to design new monitoring systems from scratch, in ways that enable the data to be used successfully to promote adaptive management of forests to achieve multiple objectives. So what would such an ideal system look like? How could it be tailored to suit the needs of the community and the resources available? How can we apply what we have learnt from our experience on this study tour?

We suggest that an ideal system would contain the following features at national and state-levels:

- A *governance structure involving stakeholders at national- or state-levels*

  The best examples of successful biodiversity monitoring programs in North America (and Europe; Kavanagh 2007) were those having clear directions provided by government. Biodiversity monitoring programs are long-term commitments that will fail without adequate commitment, support, and funding provided by government and industry. So, to ensure success, programs need to closely align data collection and reporting to the needs of user groups.

  State Governments, as the jurisdiction responsible for land management in Australia, should establish a dedicated unit or semi-independent authority to provide the funding security, institutional framework and competency needed to co-ordinate the long-term, routine and systematic collection of biodiversity information throughout each state. These units or authorities would also be responsible for data analysis, data transparency and storage, and the tailored reporting of results for a wide range of government and industry clients.

  The Australian Government has a role to encourage compatibility and flows of information between state or regional agencies and to ensure that data reporting is sufficient to meet the objectives of international and national policies and agreements (e.g. the Montreal process). It would act as a knowledge broker and would inform policy decision-makers of the outcomes relevant to forest management/utilisation practices at the national-level. State or regional committees would ensure that appropriate mixes of activities were undertaken to address key questions about trends in biodiversity across the jurisdiction (trend monitoring) and to answer specific management questions using a mix of effectiveness monitoring and strategic research.

- *A state-level trend monitoring program involving biodiversity and land management agencies, including forest management agencies*

  Australian government agencies (conservation and forestry departments), as well as private industry, have reporting obligations imposed by a range of state, national and international policies and agreements, and these reports require comprehensive data on trends and cumulative impacts on biodiversity. Assessing trends in the distribution and abundance of animals and plants across their ranges in Australian states, as well as the cumulative impacts of land management practices on them, is crucial for providing information needed to conserve and manage biodiversity.

  A coordinated and complementary set of approaches is needed to assess temporal trends in the relative abundance of species and their habitats at multiple spatial scales. These approaches include:

a. remote-sensing using aerial photography, air-borne or satellite imagery to track broad area changes in forest cover extent and fragmentation (by vegetation community where possible), and the presence or condition of many forest structural attributes

b. trend monitoring (repeated measures at permanent plots) for easily sampled groups of flora and fauna at a large set of sites, to track changes in those species and provide early warning about changes in ecological processes upon which they depend. Vascular plants, birds and several other fauna groups are among the obvious candidates for trend monitoring because the species are relatively well known and they can be sampled effectively using established techniques. Trend monitoring for biodiversity should be undertaken at permanent sites established at regular intervals (e.g. 20 km) using the national mapping grid

c. research (retrospective and experimental) to establish relationships between the habitat requirements of many species and remotely-sensed forest attributes, to investigate unexpected trends in the status of relatively common species and to provide information about the status and requirements of uncommon or rare species.

  The options fit a hierarchy of methods depending on drivers, goals and objectives, priorities, resources, governance structures and institutional competency. This could be driven/co-ordinated by an independent not-for-profit organisation, hosted by a university or government research institute. This organisation would be responsible for designing and implementing a broad-scale monitoring program to provide information on the condition of a natural resource (biodiversity) value taking into account cumulative effects of land-use practices across the landscape.

- *A range of integrated research and monitoring systems tailored for specific legislation, policies and practices (e.g.* Tasmanian Forest Practices Act 1985*)*

  These would address specific management questions. The questions would be driven largely by the legislative and policy context and the desires of the local communities. The details of particular monitoring programs proposed for each of our organisations, to evaluate the effectiveness of the legislation, policies and forest management strategies they administer/deliver, will be covered in separate future reports by each of the authors. These monitoring programs, however, need to be complementary and information from each will need to feed into higher state and Australian Government reporting systems.

- *Monitoring program designs that take into account the considerations provided above*

  One of the most important aspects of the design phase is to establish the right mix of approaches, from trend monitoring to targeted research. The choice of target species is often driven by legislative requirements (e.g. the need to focus on particular threatened species), at the expense of more general questions about biodiversity. Another approach is to select a broad range of species for monitoring from a subset of those known to be most sensitive to disturbance and which are representative of a range of functional groups (e.g. Kavanagh *et al*. 2004). Most jurisdictions recognise the need for an appropriate balance, but often lack effective mechanisms for striking that balance or ensuring that the most important strategic questions are addressed by monitoring and research projects. We see a value in establishing mechanisms to do that. All involved need to reach broad agreement on how the results will be interpreted and used to change management strategies for a particular objective. Methods used would depend on the particular objective/target/indicator but could include the presence or condition of habitat surrogates. Trend monitoring and strategic research should consider a broad suite of flora and fauna species of interest to people. Compliance monitoring should be conducted on a sample of sites, to ensure that rules are followed. Over time the monitoring program will need to be adapted to include monitoring of the effectiveness of new management initiatives, with appropriate benchmarks.

- *Identification of complementary research needs.*

  Targeted complementary research and species-specific monitoring will be required for several reasons as outlined above. For example, grid-based trend monitoring is unlikely to provide sufficient information about rare or localised threatened species. More importantly, trend monitoring can alert agencies to ecological processes that may be impacting on their domain, but more detailed investigation is likely to be needed to identify causes and appropriate management responses. Complementary experimental work may also be needed. Retrospective research and modelling can provide timely information about likely effects of new management initiatives or options.

- *An agreed process for feedback and communication with forest managers*

  Regular and effective multi-way communication is needed between staff involved in monitoring or research activities, and staff involved in land management and setting land-use policy. This is needed to ensure that strategic and management implications of the monitoring and research are considered appropriately in devising new forest policies and management strategies and revising objectives and management prescriptions. It is also needed to ensure that monitoring and research programs continue to provide the sort of information that agencies need to continuously improve their land-use policies and management practices.

We recognise a strong need for a coordinated and complementary set of monitoring approaches. We give prime consideration to our own states in Australia but also note that some of these approaches and considerations may have useful applications in many jurisdictions around the world.

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Appendix A
Itinerary and key contacts for study tour of the effectiveness monitoring and adaptive management programs for forest biodiversity in North America.

Date	Location	Activity	Contact	Affiliation
18 April	Sydney–Vancouver	Flight to Canada–USA		
19 April	Seattle, WA	Introduction, background and long-term perspectives on US Forest Service North-west Forest Plan	Prof. Jerry Franklin	College of Forest Resources, University of Washington
	Olympia, WA	Monitoring program for the Marbled Murrelet	Dr Marty Raphael	US Forest Service, PNW Research Station
20 April	Olympia, WA	WA state responses to NWFP monitoring requirements, and forest-site inspections	Dr Richard Bigley	Department of Natural Resources WA
21 April	Portland, OR	High-level administration of NWFP.	Dr Shawne Mohoric	US Forest Service, NWFP Monitoring Program Director and Team Leaders
		Vegetation and habitat monitoring	Dr Melinda Moeur	
		Aquatic and riparian monitoring	Dr Steve Lanigan	
22 April	Portland, OR	Northern Pygmy Owl biology and ecology	Mr John Deschler	Audubon Society of Portland OR
	Salem, OR	OR state responses to NWFP monitoring requirements	Dr Andrew Yost	Department of Forestry, OR
	Corvallis, OR	Regional implementation of the NWFP	Geoff Uebel Jane Curtis Doug Lavich Chris Moyer Paul Thomas Stuart Johnson John Sanchez	US Forest Service, Siuslaw National Forest

Date	Location	Activity	Contact	Affiliation
		Monitoring vegetation, owls and amphibians under the NWFP; progress in remote-sensing	Prof. Tom Spies Prof. Fred Swansson Dr Eric Forsman Dr Dede Olson Prof. Brenda McComb	US Forest Service, PNW Research Station, and College of Forest Resources, Oregon State University (OSU)
23 April	Springfield, OR	Regional implementation of the NWFP	Cheryl Friesen, Jenny Lippert Alison Rieger Nancy Sawtelle	US Forest Service, Willamette National Forest
		HJ Andrews LTER, forest-site inspections; Monitoring program for the N. Spotted Owl	Prof. Tom Spies Prof. Andy Moldenke Dr Steve Acres	US Forest Service, PNW Research Station, and OSU
24 April	Salem, OR	Baskett Slough Wildlife Refuge	Prof. Andy Moldenke	Oregon State University
	Eugene, OR	Cascade Wildlife Rehabilitation Centre	Dr Eric Forsman	US Forest Service, PNW Research Station
25 April	Corvallis – Vancouver	Drive to Vancouver, via Mt St. Helens NP		
26 April	Vancouver, British Columbia	Effectiveness monitoring programs for fauna and habitat; adaptive management	Prof. Fred Bunnell Dr Laurie Kremsater Dr Kathy Martin	Department of Forest Sciences, University of British Columbia
27 April	Victoria, British Columbia	Biodiversity monitoring in British Columbia Forest and Range Evaluation Program	Dr Richard Thomson Dr Kathy Paige	Ministry of Environment British Columbia
			Tory Stevens	National Parks, British Columbia
			Dr Peter Bradford Dr Peter Tchaplinski Dr Nancy Densmore Dr Melissa Todd Laura Darling Lars Rhys Hansen	Ministry of Forest and Range, British Columbia
		FREP Act Forest planning and practices regulation	Dr Marvin Eng John Pennington Rose Keats	Forest Practices Board, British Columbia

Date	Location	Activity	Contact	Affiliation
		FREP monitoring Mtn. Pine Beetle issue	Dr Andy MacKinnon Dr Jim Goudie	Ministry of Forest and Range, British Columbia
28 April	Victoria, British Columbia	Forest ecosystem classification, inventory and representation in protected areas network	Dr Liz Williams Rob Paynter	Ministry of Forest and Range, British Columbia Integrated Land Management Bureau Ecosystem-based Management program
		Description and management of ecosystem 'variants'	Dr Rod Negrave Dr Andy MacKinnon	Ministry of Forest and Range, British Columbia Ecosystem Research
29 April	Campbell River, British Columbia	Landscape-level planning, effectiveness monitoring and certification on private industrial forest land	Dr Warren Warttig	Interfor (International Forest Products Ltd.)
30 April	Campbell River, British Columbia	Adaptive management research and monitoring program, and forest certification on private industrial forest land	Dr Bill Beese	Western Forest Products (previously MacMillan Bloedel and Weyerhauser, now Island Pacific)
	Nanaimo, British Columbia	Research underpinning habitat classifications for threatened species and communities, and biodiversity monitoring programs (FREP)	Dr Melissa Todd Dr Louise Waterhouse Dr Sari Saunders Derek Challenger Dr Rod Negrave	Ministry of Forest and Range, British Columbia Ecosystem Research
1 May	Ucluelet, British Columbia	Forest site inspections MacMillan Forest Preserve	Jeff Meggs	Ecological consultant

Date	Location	Activity	Contact	Affiliation
		First Nations hydro-electricity enterprise Water quality monitoring		
2 May	Smithers, British Columbia	Effectiveness monitoring Risk management Forest site inspections Mountain Pine Beetle	Dr Karen Price Dave Daust	Babine Watershed Monitoring Trust
3 May	Smithers, British Columbia	Babine Watershed Monitoring Program Trust – role, legal basis, and administration Conservation issues and ecologically sustainable forest management Owl survey	Dr Karen Price Dave Daust Richard Overstall Tom Buri Dr Jim Pojar Frank Doyle	Babine Watershed Monitoring Trust Environmental law practice British Columbia Department of Forestry (Research) Ecological consultant
4 May	Edmonton, AB	Fly to Edmonton via Vancouver		
5 May	Edmonton, AB	Alberta Biodiversity Monitoring Program	Professor Stan Boutin Dr Jim Schieck Dr Jim Herbers	Alberta Biodiversity Monitoring Institute, University of Alberta Alberta Innovates – Technology Futures
6 May	Edmonton, AB	Conservation and forest management in Alberta Elk Island National Park Endangered species management	Dr John Stadt Dr Gordon Court	Department of Sustainable Resource Development, Forestry Div., Alberta Canadian Fish and Wildlife Service, Alberta
7 May	Vancouver, British Columbia	Fly to Vancouver Writing report		

Date	Location	Activity	Contact	Affiliation
8 May	Vancouver, British Columbia	Writing report Capilano Heritage Forest Park		
9 May	Vancouver – Sydney	Flight to Australia		
10 May	Vancouver – Sydney	Flight to Australia		

Appendix B
Questions

- How is biodiversity managed in wood production forest areas (and across other land tenures)?
- What are the objectives/goals/desired outcomes in policy and/or codes of practice and how are these developed?
- How is the effectiveness of measures to achieve the objectives for biodiversity assessed? In particular:

    How does monitoring fit within a research framework and who is responsible?

    What are the advantages /disadvantages of different spatial and temporal designs for monitoring aspects of biodiversity (e.g. grid-based vs. adaptive management approach)?

    What use is made of single-species vs. multi-species approaches?

    Decisions on which objectives, projects/species to monitor?

    Price et al work

    To what extent is remote-sensing of forest structural attributes employed as part of the program?

- How is new information obtained and taken into account in on-ground management.

    How are the results of research translated into policy and practice?

    Who is responsible for achieving this?

    What is the adaptive management process?

    What approaches, if any, are taken to engage public participation and inputs to the monitoring process throughout the various stages of program development?

    What planning tools are used? (Use of remote sensing/habitat surrogates/forest inventory/habitat modelling).

- What does the program cost?
- What is the reporting process, at which levels?
- How is data storage and information transparency achieved?
- What measures are used to determine whether the biodiversity monitoring program is 'cost-effective'
- What evidence is there that the biodiversity monitoring program has produced results that have satisfied forest managers, regulators and the general public that both biodiversity and other forest values are being managed sustainably?

Appendix C
Example of objectives, desired outcomes and practice requirements listed in the regulations of the current *British Columbia Forest and Range Practices Act 2005*

<www.for.gov.bc.ca/tasb/legsregs/>

Forest and Range Practices Act 2005

Forest planning and practices regulation

Objectives set by government for wildlife

7(1) The objective set by government for wildlife is, without unduly reducing the supply of timber from British Columbia's forests, to conserve sufficient wildlife habitat in terms of amount of area, distribution of areas and attributes of those areas, for

(a) the survival of species at risk,

(b) the survival of regionally important wildlife, and

(c) the winter survival of specified ungulate species.

(2) A person required to prepare a forest stewardship plan must specify a result or strategy in respect of the objective stated under subsection (1) only if the minister responsible for the *Wildlife Act* gives notice to the person of the applicable

(a) species referred to in subsection (1), and

(b) indicators of the amount, distribution and attributes of wildlife habitat described in subsection (1).

(3) If satisfied that the objective set out in subsection (1) is addressed, in whole or in part, by an objective in relation to a wildlife habitat area or an ungulate winter range, a general wildlife measure, or a wildlife habitat feature, the minister responsible for the *Wildlife Act* must exempt a person from the obligation to specify a result or strategy in relation to the objective set out in subsection (1) to the extent that the objective is already addressed.

(4) On or after December 31, 2004, a notice described in subsection (2) must be given at least 4 months before the forest stewardship plan is submitted for approval.

[am. B.C. Reg. 580/2004, s. 7.]

Objectives set by government for wildlife and biodiversity — landscape-level

9 The objective set by government for wildlife and biodiversity at the landscape-level is, without unduly reducing the supply of timber from British Columbia's forests and to the extent practicable, to design areas on which timber harvesting is to be carried out that resemble, both spatially and temporally, the patterns of natural disturbance that occur within the landscape.

[en. B.C. Reg. 580/2004, s. 8.]

Objectives set by government for wildlife and biodiversity — stand-level

9.1 The objective set by government for wildlife and biodiversity at the stand-level is, without unduly reducing the supply of timber from British Columbia's forests, to retain wildlife trees.

[en. B.C. Reg. 580/2004, s. 8.]

Practice Requirements

Division 5 — Biodiversity

Maximum cutblock size

64 (1) If an agreement holder other than a holder of a minor tenure harvests timber in a cutblock, the holder must ensure that the size of the net area to be reforested for the cutblock does not exceed

(a) 40 hectares, for the areas described in the Forest Regions and Districts Regulation that are listed in Column 1, and

(b) 60 hectares, for the areas described in the Forest Regions and Districts Regulation that are listed in Column 2.

Wildlife tree retention

66 (1) If an agreement holder completes harvesting in one or more cutblocks during any 12 month period beginning on April 1 of any calendar year, the holder must ensure that, at the end of that 12 month period, the total area covered by wildlife tree retention areas that relate to the cutblocks is a minimum of 7% of the total area of the cutblocks.

(2) An agreement holder who harvests timber in a cutblock must ensure that, at the completion of harvesting, the total amount of wildlife tree retention areas that relates to the cutblock is a minimum of 3.5% of the cutblock.

(3) For the purposes of subsection (1) and (2), a wildlife tree retention area may relate to more than one cutblock if all of the cutblocks that relate to the wildlife tree retention area collectively meet the applicable requirements of this section.

Appendix D
Species observed during study tour

Birds		
Pacific loon	*Gavia pacifica*	One on Lake Kennedy, Vancouver Is
common loon	*Gavia immer*	50+ in Tsawwassen Harbour (near Vancouver, ferry terminal for Vancouver Is), breeding plumage; loose groups sometimes porpoising after fish; also pair on Lake Tahu near Smithers, calling eerily at dusk
horned grebe	*Podiceps auritus*	4 Tsawwassen Harbour, breeding plumage
American white pelican	*Pelecanus erythrorhynchos*	3 flew high over Elk Lake NP
double-crested cormorant	*Phalacrocorax auritus*	Several along coasts
Brandt's cormorant	*Phalacrocorax penicillatus*	Several along coasts
pelagic cormorant	*Leucocarbo pelagicus*	5 Tsawwassen Harbour; several from ferry to Vancouver Is
great blue heron	*Ardea herodias*	A few in swamps and estuaries; one squawked from treetop Univ of Washington, Seattle; several Victoria & Nanaimo (Vancouver Is: said to be scarce in Canada)
mute swan	*Cygnus olor*	Two on river Salem
snow goose	*Chen caerulescens*	One with Lesser Canada Geese Baskett Slough near Corvallis
Canada goose	*Branta canadensis*	10 000+ in pastures Baskett Slough (‘lesser’ subspecies, short necks); pairs common on coasts and wetlands, one with brood of 6+ young (Nanaimo)
black brant (brent goose)	*Branta bernicla*	~40 on sea Tsawwassen Harbour; flock of 400 flew north & landed on mudflats

		Parksville (Vancouver Is)
Carolina wood duck	*Aix sponsa*	Pair on fast stream HJ Andrews
American wigeon	*Anas americana*	Two on grassy meadow Baskett Slough
gadwall	*Anas strepera*	10 Baskett Slough
green-winged teal	*Anas carolinensis*	15+ Baskett Slough; a few on wetlands elsewhere, eg Elk Lake NP
mallard	*Anas platyrhynchos*	Common on wetlands, eg Baskett Slough and Elk Lake NP, and town park lakes, eg Green Lake in Seattle (though fewer than I'd expected)
northern pintail	*Anas acuta*	50 in muddy estuary Canada-USA border; 4 flew over lagoon near Victoria; a few Elk Lake NP
cinnamon teal	*Anas cyanoptera*	Two Baskett Slough
northern shoveler	*Anas clypeata*	50+ Baskett Slough
lesser scaup	*Aythya affinis*	Pair Baskett Slough; a few unidentified scaup on sea Tsawwassen Harbour and on lakes near Smithers
harlequin duck	*Histrionicus histrionicus*	15 close offshore from our hotel, Campbell River
black scoter	*Melanitta nigra*	Group of 4 (2 males followed by 2 females) from ferry off Nanaimo: females looked much paler-headed than I remember for the European equivalent = Common Scoter
surf scoter	*Melanitta perspicillata*	30+ Tsawwassen Harbour; others at sea from ferry and on coasts of Vancouver Is
white-winged scoter	*Melanitta fusca*	2 with flock of Surf Scoter and 4 flying separately Tsawwassen harbour
bufflehead	*Bucephala albeola*	3 on wetland Baskett Slough; 42 on Muir Creek estuary; 12 in sheltered bay near Victoria

red-breasted merganser	*Mergus serrator*	Pair with a pair of Goosanders in sea campbell River; 4 flew past ferry near Nanaimo
common merganser (goosander)	*Mergus merganser*	Common in wetlands, large rivers and shallow sea
turkey vulture	*Cathartes aura*	Common mainly in farmland and near towns
osprey	*Pandion haliaetus*	Pair nesting at lake near airport, Smithers; last year's nest on pole Corvallis
bald eagle	*Haliaeetus leucocephalus*	Several along coasts; adult soaring over Seattle; immature fishing Green Lake, Seattle; pair and an immature in conifer behind hotel Campbell River
red-tailed hawk	*Buteo jamaicensis*	Common in farmland and mountain forests
American kestrel	*Falco sparverius*	A few in farmland, sometimes on wires, eg near Corvallis
merlin	*Falco columbarius*	One causing havoc among ducks Elk Lake NP near Edmonton
wild turkey	*Meleagris gallopavo*	A few in wooded gardens beside road near Mt St Helens
ruffed grouse	*Bonasa umbellus*	Rod flushed one from understorey in deciduous forests Elk Lake NP
sandhill crane	*Grus canadensis*	Flock heard flying over lake near Smithers; hundreds seen & heard flying north in several flocks over Elk Lake NP
American coot	*Fulica americana*	A few Green Lake, Seattle and Baskett Slough, near Corvallis
black oystercatcher	*Haematopus bachmani*	Pair feeding from rocks Victoria; a few among rocks on west coast of Vancouver Is
black-necked stilt	*Himantopus mexicanus*	Two in shallows of large lake, Elk Lake NP
American avocet	*Recurvirostra americana*	Two with stilts in shallows of large lake, Elk Lake NP
grey plover (black-bellied plover)	*Pluvialis squatarola*	Flock of 80 Tsawwassen Harbour; one in lagoon near Andy McKinnon's house near

		Victoria, all in breeding plumage
killdeer	*Charadrius vociferus*	One in muddy creek Okuk Valley near Olympia
semipalmated plover	*Charadrius semipalmatus*	Pair on pebbly beach near Victoria, remarkably cryptic
short-billed dowitcher	*Limnodromus griseus*	One feeding in muddy lagoon near Andy McKinnon's house near Victoria, in breeding plumage: much smaller than adjacent Grey Plover
long-billed curlew	*Numenius americanus*	Flock of 100 in wet pasture Salem, next to open industrial estate
lesser yellowlegs	*Tringa flavipes*	One in muddy estuary Canada-USA border; a few Elk Lake NP
western sandpiper	*Calidris mauri*	One at rock-pools on west coast of Vancouver Is (near Uchuelet); flock of small waders Canada-USA border may have been this species
mew gull	*Larus canus*	A few on coastal mudflats Vancouver Is, eg Campbell River
ring-billed gull	*Larus delawarensis*	Fairly common in suburbs of Edmonton, possibly nesting
glaucous-winged gull	*Larus glaucescens*	Common in small numbers on coasts, Vancouver & Vancouver Is; a few further south
western gull	*Larus occidentalis*	Common on coasts and in coastal towns in USA, nesting on flat rooves; a few in Canada, perhaps intergrading with Glaucous-winged
bonaparte's gull	*Larus philadelphia*	One on coastal mudflats Canada-USA border; flock of 200 near possible nesting island near Victoria; flock on shore Campbell River; a few Elk Lake NP, on muddy lake shore and calling in flight over forest
caspian tern	*Sterna caspia*	One on coast Canada–USA border
pigeon guillemot	*Cepphus columba*	Several Tsawwassen Harbour, Nanaimo Habour and from ferries to & from Vancouver Is

marbled murrelet	*Brachyramphus marmoratus*	One on sea off Nanaimo Harbour
rock dove	*Columba livia*	Feral birds in towns
mourning dove	*Zenaida macroura*	A few in farmland near Corvallis, often on wires
barred owl	*Strix varia*	One responded to playback late afternoon Eugene, & continued calling in full view high in conifer; two heard calling in young conifer forests near Smithers
northern pygmy-owl	*Glaucidium californicum*	One flushed from nest hollow in small dead conifer in Audubon Society park Portland soon after dawn
northern saw-whet owl	*Aegolius acadicus*	One responded to playback and flew around our heads in tight circles at night in young conifer forests near Smithers
Vaux's swift	*Chaetura vauxi*	Flock of 20 over farmland near Corvallis
Anna's hummingbird	*Calypte anna*	A male and later a female in woods beside Green Lake, Seattle; a few elsewhere
rufous hummingbird	*Selasphorus rufus*	Several near Smithers, including a male defending a patch of yellow tubular flowers in farmland from another male; several at feeders
belted kingfisher	*Megaceryle alcyon*	Singles Muir Creek estuary and at beach near Andy McKinnon's house near Victoria
red-naped sapsucker	*Sphyrapicus nuchalis*	One feeding from broken treetop in deciduous forest, Elk Lake NP; very loud rapping heard from this and another
red-breasted sapsucker	*Sphyrapicus ruber*	One feeding from tall conifer near visitor centre Mt St Helens; Sarah aslo saw one in conifer forest at visitor centre Mt Rainier
downy woodpecker	*Picoides pubescens*	One feeding in outer branches of deciduous trees Elk Lake NP, appearing to be working in association with a hairy WP that kept to the trunks

hairy woodpecker	*Picoides villosus*	Several feeding mainly from trunks and large branches of coniferous and deciduous trees Mt Rainier, Smithers (visiting Karen & Dave's feeders) and Elk Lake NP
northern flicker	*Colaptes auratus*	Several in treed farmland near Olympia and Smithers, and in deciduous forest Elk Lake NP
pileated woodpecker	*Dryocopus pileatus*	One heard and seen briefly in mature conifer forest HJ Andrews; one seen well in deciduous forest Elk Lake NP (where it was one of 5 woodpecker species, and the only other bush-birds were a nuthatch, robins and a couple of unidentified small birds)
western wood-pewee	*Contopus sordidulus*	Pair in mixed forest near Smithers
tree swallow	*Tachycineta bicolor*	A few over wetlands Baskett Slough and probably elsewhere
violet-green swallow	*Tachycineta thalassina*	Common over wetlands Baskett Slough, Smithers, etc; seemed to be checking out nest sites under eaves of hotel, Corvallis-on-the-river and buildings at Grouse Mt, Vancouver
cliff swallow	*Pertochelidon pyrrhonota*	Two singles over wetlands and grassland Baskett Slough
barn swallow	*Hirundo rustica*	A few over wetlands and farmland several locations including Olymoia, Baskett Slough and Smithers
golden-crowned kinglet	*Regulus satrapa*	Two in woods near Green Lake, Seattle
ruby-crowned kinglet	*Regulus calendula*	A few in conifer forests, eg Mt Rainier and Smithers, often flycatching actively from deciduous trees (much more so than Goldcrests do in Europe)
Bewick's wren	*Thryomanes bewickii*	One in shrubs beside hotel and river, Corvallis, probably nesting
winter wren	*Troglodytes troglodytes*	Fairly common in understorey of conifer forests, eg Mt Rainier, Campbell River, Smithers; song more varied than in Europe.
house wren	*Troglodytes aedon*	Two in understorey of mature conifer forest Cathedral Grove on Vancouver Island,

		giving loud very agitated alarm calls; tails much longer than winter wren
mountain bluebird	*Sialia currucoides*	One in treed farmland near Smithers
Swainson's thrush	*Catharus ustulatus*	One seen briefly in forest Muir Creek: apparently this species is a common migrant in coniferous forests
American robin	*Turdus migratorius*	Common in forests and town parks
varied thrush	*Ixoreus naevia*	Several mainly in conifer forests, eg Mt Rainier and Cathedral Grove on Vancouver Is, feeding from shady ground or mossy stumps; call a strange long, high-pitched trill
red-breasted nuthatch	*Sitta canadensis*	Common in conifer and mixed forests, eg HJ Andrews, Eugene and Smithers, visiting feeders at Karen & Dave's; call a strange frog-like bleeting double note, 'zeeb zeeb'
white-breasted nuthatch	*Sitta carolinensis*	One in deciduous forest Elk Lake NP; call like Red-breasted but louder
brown creeper	*Certhia americana*	One probably heard singing in mature conifer forest Canoe Creek, Vancouver Island
gray jay	*Perisoreus canadensis*	Several near visitor centre Mt Rainier, very tame
Steller's jay	*Cyanocitta stelleri*	Locally common in parks (eg Seattle, Grouse Mt) and conifer forests, eg Mt Rainier
western scrub-jay	*Aphelocoma californica*	One or two in town park near hotel Corvallis-on-the-river, tame
black-billed magpie	*Pica hudsonia*	Common in suburbs of Edmonton & nearby farmland; pair feeding from bison-pats in grassland Elk Lake NP
American crow	*Corvus brachyrhynchos*	Common in farmland and some towns
north-western crow	*Corvus caurinus*	Common in farmland, towns and coast Vancouver Island (where American Crow is absent)
common raven	*Corvus corax*	Fairly common in forests and mountains, eg HJ Andrews, Vancouver Island, Smithers (5

		together in town), etc
common starling	*Sturnus vulgaris*	Small flocks in farmland & grassland
house sparrow	*Passer domesticus*	Fairly common in most towns
purple finch	*Carpodacus purpureus*	One came to Karen & Dave's feeders near Smithers
house finch	*Carpodacus mexicanus*	A few in several towns (eg Olympia, Victoria), singing sweetly from town trees
red crossbill	*Loxia curvirostra*	Several calling in conifer forests HJ Andrews and Campbell River; one female seen on top of small conifer Grouse Mt, Vancouver
pine siskin	*Carduelis pinus*	Common in conifer forests; many coming to Karen & Dave's feeders near Smithers
evening grosbeak	*Coccothraustes vespertina*	Two seen well in tops of Douglas Fir and many calling nearby near Olympia
yellow-rumped warbler	*Dendroica coronata*	Common in open wooded areas, presumably on migration, eg Green Park, Seattle, Baskett Slough and near airport Smithers (where many were feeding from ploughed fields); most were of yellow-throated ‘Audubon's’ form but one at Seattle had a white throat typical of eastern birds
Wilson's warbler	*Wilsonia pusilla*	A female in shrubs beside river Corvallis; less positive identifications of one singing in deciduous woodland Muir Creek, and one singing from low conifer in forested hills near Campbell River (MASS project)
chipping sparrow	*Spizella passerina*	One in shrubbery near forest offices Salem
song sparrow	*Melospiza melodia*	One singing from tall deciduous tree in wooded farmland Smithers; others heard
white-crowned sparrow	*Zonotrichia leucophrys*	Common in farmland, along roadsides and in grassy clearings in forest, eg Mt Rainier
golden-crowned sparrow	*Zonotrichia atricapilla*	Flock of 8 foraging in snow patch in hills near Campbell River (MASS project)

dark-eyed junco	*Junco hyemalis*	Common in scrub, forest clearings and gardens, often on bird tables or below feeders
red-winged blackbird	*Agelaius phoeniceus*	Common in farmland and marshes; strange twanging song, stuttering like brown songlark; discordant calls
brown-headed cowbird	*Molothrus ater*	One in an urban tree Victoria; others probably seen in farmland but not as common as expected
Mammals		
opossum	*Didelphis marsupialis*	Several dead on roads
Townsend mole or Pacific mole	*Scapanus townsendi or S. orarius*	Lots of diggings in swampy river flats Mt Rainier, and suburban lawns Victoria
river otter	*Lutra canadensis*	One on rocky wharf Nanaimo (Vancouver Is)
striped skunk	*Mephitis mephitis*	Several dead on roads
coyote	*Canis latrans*	A few heard at night in forest near Smithers
(American) red fox	*Vulpes fulva*	One ran across road in daylight from tree plantation near Corvallis, carrying animal (rabbit or ground squirrel), and seen nearby after dark
harbor seal	*Phoca vitulina*	8 in bay at Andy McKinnon's house near Victoria; 1 in harbour Vancouver
California ground squirrel	*Citellus beecheyi*	5+ in grassland Baskett Slough near Corvallis; one rubbing itself on gravel path
Richardson's ground squirrel	*Citellus richardsoni*	Many in grassland Elk Lake NP, near Edmonton
western grey squirrel	*Sciurus griseus*	4 eating new leaf shoots of deciduous trees Green Lake, Seattle

(American) red squirrel	*Tamiasciurus hudsonicus*	One at feeders near Smithers (Karen & Dave); one in deciduous forest understorey Elk Lake NP near Edmonton
Douglas squirrel (chickaree)	*Tamiasciurus douglasi*	2 seen in conifers HJ Andrews; a few heard in conifer forests elsewhere (hard gutteral trill)
meadow vole	*Microtus pensylvannicus*	An unidentified vole seen in understorey of deciduous forest Elk Lake NP, in range for this common species
(American) porcupine	*Erethizon dorsatum*	One spotlit beside gravel road in young conifer forest near Smithers
nutria (coypu)	*Myocastor coypus*	One swimming along river edge Baskett Slough, sometimes climbing onto grassy bank
eastern cottontail	*Sylvilagus floridanus*	Two in shrubby grassland next to picnic site Baskett Slough
mule deer (black-tailed deer)	*Odoicoileus hemionus*	A few in forest Mt Rainier, seen feeding in swampy river flats and beside road
moose	*Alces alces*	Two spotlit in deciduous forest near Smithers; scats found in many places
(American) bison	*Bison bison*	Many in grassland and among deciduous woodland Elk Lake NP, near Edmonton; a frisky male at picnic area
grey whale	*Eschrichtius gibbosus*	A distant whale seen from ferry out of Nanaimo, was probably this species: frequent low spouts, finless grey back
Reptiles		
red-eared slider (common slider turtle)	*Trachemys scripta*	19 basking on two small logs, Green Lake, Seattle
maybe too cool for other reptiles		

Amphibians	
frog sp.	Lots calling in swamp Elk lake NP; a few in forest elsewhere
no sign of salamanders, though several species occur in forest wetlands	