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# CUMULATIVE ECOLOGICAL AND SOCIOECONOMIC EFFECTS OF FOREST POLICIES IN COASTAL OREGON

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*Abstract*. Forest biodiversity policies in multi-ownership landscapes are typically developed in an uncoordinated fashion with little consideration of their interactions or possible unintended cumulative effects. We conducted an assessment of some of the ecological and socioeconomic effects of recently enacted forest management policies in the 2.3-million-ha Coast Range Physiographic Province of Oregon. This mountainous area of conifer and hardwood forests includes a mosaic of landowners with a wide range of goals, from wilderness protection to high-yield timber production. We projected forest changes over 100 years in response to logging and development using models that integrate land use change and forest stand and landscape processes. We then assessed responses to those management activities using GIS models of stand structure and composition, landscape structure, habitat models for focal terrestrial and aquatic species, timber production, employment, and willingness to pay for biodiversity protection. Many of the potential outcomes of recently enacted policies are consistent with intended goals. For example, we project the area of structurally diverse older conifer forest and habitat for late successional wildlife species to strongly increase. Other outcomes might not be consistent with current policies: for example, hardwoods and vegetation diversity strongly decline within and across owners. Some elements of biodiversity, including streams with high potential habitat for coho salmon (*Oncorhynchus kisutch*) and sites of potential oak woodland, occur predominately outside federal lands and thus were not affected by the strongest biodiversity policies. Except for federal lands, biodiversity policies were not generally characterized in sufficient detail to provide clear benchmarks against which to measure the progress or success. We conclude that land management institutions and policies are not well configured to deal effectively with ecological issues that span broad spatial and temporal scales and that alternative policies could be constructed that more effectively provide for a mix of forest values from this region.

*Key words: biodiversity; forest management; landscape patterns; old growth; ownership effects; salmon habitat; timber production; wildlife habitat.*

## Introduction

The variety of goods and services we receive from a forest depends on the allocation of forest land uses across spatial and temporal scales (Monserud et al. 2003). It is generally recognized that all values cannot be achieved on the same area of forest (Stevens and Montgomery 2002). Consequently, in practice, most forest owners use some combination of zoning and multiple use to achieve their goals. It is also recognized that compatibility of uses increases with spatial and temporal extent (Monserud et al. 2003). The clearest example of this occurs in large landscapes or subregions, where multiple forest values are achieved simply because of the diversity of ownerships and owner's goals. While large multi-owner landscapes can produce a variety of goods and services, we know little about how patterns and practices of forest owners influence biodiversity and socioeconomic conditions in a region. The variety of management goals and practices in multi-ownership landscapes may have unintended cumulative effects that are not recognizable within a single ownership. Most studies of the compatibility and effects of forest management have either focused within ownerships at the stand level, which is inadequate to address the problem, or among ownerships at the regional level

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using highly aggregated data and ignoring spatial pattern (Stevens and Montgomery 2002).

In this paper and others that follow, we describe a regional assessment of forestlands of the Oregon Coast Range Physiographic Province. Our effort—the Coastal Landscape Analysis and Modeling Study (CLAMS)—is an attempt to assess some of the ecological and socioeconomic consequences of recently enacted forest policies in this 2.3-million-ha multi-ownership region (Spies et al. 2002*b*). CLAMS is unique in that it followed a forest management crisis in which timber cutting and other operations were halted on federal forests in the range of the Northern Spotted Owl (*Strix occidentalis*) by federal court orders. The President of the United States then commissioned an ecosystem assessment (Forest Ecosystem Management Assessment Team 1993) to identify options for solving the crisis. The President chose an option that became the Northwest Forest Plan (NWFP; USDA Forest Service and USDI Bureau of Land Management 1994). That plan provided federal funding to the USDA Forest Service Pacific Northwest Research Station for follow-up research including CLAMS. The Forest Ecosystem Management Assessment Team assessment sparked the interest of a group of scientists who devoted considerable attention to the interaction between science and policy. CLAMS is both a follow-up assessment that evaluates the recent biodiversity policies as hypotheses, and an anticipatory assessment that allows decision makers (policy makers, managers, and the public) to question the direction of current and alternative policies based on different social, economic, or ecological assumptions and outcomes.

In the 1990s, new policies for federal, state, and private forestlands in Oregon increased the emphasis on conserving biological diversity. The policies were developed one ownership class at a time with only limited consideration of the aggregate effects of policies and practices across ownerships. Federal policies were developed based on emerging ideas in conservation biology (e.g., reserve design for threatened populations) and ecosystem management (e.g., disturbance ecology) that had never been applied at such a broad scale. Policies for state lands were also based on new approaches to meeting ecological goals through active forest management. New policies for private lands increased protection for streams and wildlife habitats, while maintaining freedom for landowners to pursue timber management goals. These novel approaches, which differed greatly among the major landowners, essentially represent untested hypotheses about the effects of mixed forest uses within and among forest ownerships.

We had two primary goals: first, we wanted to develop and evaluate concepts and tools to understand the patterns and dynamics of regional ecosystems and how they are affected by forest policies; second, we wanted to inform managers, policy makers, landowners, and other scientists about some of the potential ecological and socioeconomic consequences of current and alternative forest policies and management actions across ownerships. We posed the following specific questions:

1) What are the current conditions and possible future trends of key indicators of biodiversity and socioeconomic conditions under existing policies?

2) How consistent are these trends with current policies? In other words, how well do policies meet their objectives?

3) Do current policies enacted independently of each other leave gaps in biodiversity protection at the scale of the province?

4) How might alternative policies influence ecological and socioeconomic outcomes?

In this paper, we summarize the key findings of the papers in the Invited Feature and provide a synthesis of the effects of forest policies on measures of biodiversity and socioeconomic conditions.

## Study Area

We selected the Coast Range Physiographic Province of Oregon (Fig. 1) because it contained a diverse array of owners and management practices and had been the focus of a relatively rich body of previous scientific work upon which to base habitat and landscape simulation models (Hayes and Hagar 2002, Spies et al. 2002*a*). The province is dominated by coniferous forests growing on low-elevation, highly dissected mountains that have steep slopes, high stream densities, and orographically based climatic zones (Ohmann et al. 2007). Our general assessment area includes the fringes of the Willamette Valley on the east, but our simulation area is limited to the land within the province classified as forest land.

### *Disturbance history*

Historically, wildfire was the dominant natural disturbance in the Coast Range (Wimberly 2002). Fires tended to be large and severe, occurring with return intervals that ranged from 100 years near the valley margin to more than 200 years near the coast (Impara 1997). In presettlement times, Native Americans set fires along the Willamette valley margin that sometimes burned into the Coast Range. Native Americans had settlements near the coast, but settlements were less common in the narrow valleys of the interior. Settlement by Euro-Americans began in the mid 1800s, and in the last 100 years, human activities have become the major disturbance of the forests. In the late 1800s and early 1900s, wildfires set by settlers and loggers burned large areas of the region. Logging began in the late 1800s on private lands and after World War II on public lands (Johnson et al. 2007*a*). Blow-down of stands from wind has occurred frequently on coastal headlands (Harcombe et al. 2004) and infrequently away from the coast. Landslides and debris flows have been relatively common in steeper areas and have influenced stream habitats throughout the Coast Range (May 2002).

*Biodiversity concerns*

Current threats to native biological diversity are exemplified through three species that are listed as Threatened or Endangered by the U.S. government: the Northern Spotted Owl (*Strix occidentalis caurina*), Marbled Murrelet (*Brachyramphus marmoratus*), and chum salmon (*Oncorhynchus keta*). Coho salmon (*O. kisutch*), which was listed in the 1990s as Threatened but recently delisted, is under consideration for re-listing. Sources of threats to the two bird species include changes in forest structure and dynamics, most notably the decline of mature and old-growth forests with their large live and dead trees. The fish species are threatened by loss of floodplain and estuary habitat as well as by the influences of forest management in watersheds where they occur. A variety of other species of plants, animals, and fungi are also thought to be at risk from loss of old forest vegetation types (Forest Ecosystem Management Assessment Team 1993).

*Land use and ownership patterns*

Conifer or hardwood forest managed for forest uses covers about 78% of the Coast Range (Fig. 1). Some urban and rural residential development is concentrated on the western and eastern margins of the study area and along major rivers (5% of study area). Limited dairy farming and agriculture, occurring in the coastal lowlands along the west margin (9%) and woodlands and other vegetation, occupy about 8% of the area.

The Coast Range is a mosaic of forest ownerships (Fig. 1). Unlike other forest areas in the western United States, ownership is dominated by private landowners (63%; Table 1). The spatial pattern of ownerships ranges from large blocks to a "checkerboard" pattern of Bureau of Land Management (BLM) and private lands that creates a high potential for landscape interactions among owners. For example, 89% of the BLM lands fall within 1000 m of private forest lands (Spies et al. 2002*b*).

*Forest management goals*

The forest policy goals and management strategies of landowners in the Coast Range are diverse, ranging from intensive wood production to wilderness protection (Table 1). Until the late 1980s, federal and state lands were managed similarly to industrial lands, with high initial investment aimed at suppressing hardwoods and brush and growing conifer plantations that rapidly yielded commercial wood products. In the 1980s, nearly half of the timber volume in the region came from federal forests, with the forest industry harvesting the other half. Clearcutting was the dominant harvest method. In the late 1980s, conservation efforts and lawsuits began to reduce the volume of timber cut on federal lands and by the early 1990s federal courts halted logging on the federal lands in the range of the Northern Spotted Owl. In 1994, the NWFP (USDA Forest Service and USDI Bureau of Land Management 1994) brought sweeping changes to federal forest management in this province, dramatically shifting the focus toward protection of biodiversity. This reduced timber harvest from federal lands in the Coast Range by over 90% compared with harvest in the 1980s. Policies in management plans for state forests also shifted to emphasize biodiversity. During this time state forest practices rules for private lands have attempted to increase protection for salmon and wildlife habitat, although the goals for many private

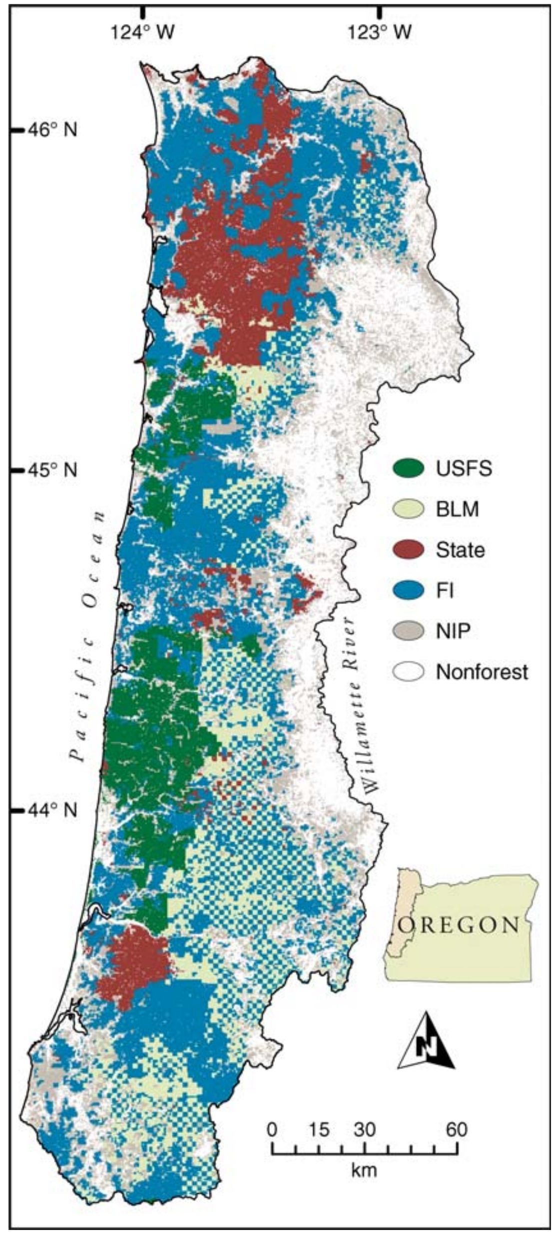


Fig. 1. Map of ownership classes for forest land in the Coast Range Physiographic Province in Oregon. Abbreviations in legend are: USFS, U.S. Forest Service; BLM, Bureau of Land Management; State, State of Oregon; FI, forest industry; NIP, nonindustrial private forest and other miscellaneous owners; nonforest, other land uses.

Table 1. Forest policies, policy goals, and management strategies dealing with biological diversity in the Oregon Coast Range Province by major ownership categories.

| Ownership | Forest area (%) | Forest policies | Policy goals |
|---|---|---|---|
| U.S. Forest Service | 10 | 1) Northwest Forest Plan (NWFP)<br>2) Individual National Forest plans | 1) Late successional/old-growth forest habitats and ecosystems; biological diversity including Threatened and Endangered species; ecological health of watersheds and aquatic ecosystems<br>2) Commodities |
| Bureau of Land Management | 15 | Same as above | Same as above |
| State Forests of Oregon | 12 | Forest plans | 1) Sustainable timber production<br>2) Properly functioning aquatic habitat; habitat for native species, protect soil, air, and water, and provide recreation |
| Forest industry | 41 | State Forest Practices Act | 1) Sustainable timber production<br>2) Protection of environment and fish/wildlife |
| Nonindustrial private | 22 | State Forest Practices Act | More diverse than forest industry but typically some level of revenue from forest land |

*Notes:* Goals are listed in approximate priority order; terms used by to describe goals are taken directly from policy documents, and meanings may not be consistent among owners. Goals may have more than one management strategy (from Spies et al. 2000).

† Matrix management involves use of special silvicultural practices to produce timber while retaining habitat elements in areas surrounding the reserves.

‡ Adaptive Management Areas are large landscapes where new approaches to meeting the goals of the NWFP can be developed and tested.

§ Structure-based management uses active management rather than reserves to achieve stand structure goals. This involves long rotations (120–150 years) and green-tree retention.

¶ Habitat Conservation Plans are landscape management plans for Threatened and Endangered species developed in conjunction with the U.S. Fish and Wildlife Service.

landowners still focus on timber production. Thus, policies for public and private lands have diverged.

The most clearly specified biodiversity policy goals are for federal forests where, under the NWFP, management is expected to maintain and restore old-growth ecosystems, providing habitat for Threatened and Endangered species (i.e., Northern Spotted Owl and Marbled Murrelets) and other species associated with mature and old-growth forests, and to maintain and restore important ecological functions of watersheds and aquatic habitat. In addition, under the diversity clause of the National Forest Management Act (NFMA), the Forest Service (BLM is not subject to this policy) must "provide for diversity of plant and animal communities ... to meet overall multiple-use objectives" (Wilkinson and Anderson 1987). Both the NWFP and NFMA call for a sustainable level ("even flow") of timber production. These goals are addressed through two major land allocations, reserves (84% of federal lands in the Coast Range), where some active management is permitted to restore ecological diversity, and matrix (15% of federal lands), where some timber harvest is allowed if green tree retention and other conservation standards and guidelines are used (USDA Forest Service and USDI Bureau of Land Management 1994).

Forests owned by the State of Oregon are under special forest management plans that pursue a complex blend of biodiversity, economic, and recreation goals. Biodiversity goals include maintaining biological diversity and providing for forest structural complexity and age diversity within and among stands (Oregon Department of Forestry 2001). Economic goals include providing sustainable timber harvest and revenues and, on some of the lands (Common School Lands), maximizing long-term revenues. For state forests in the northern Coast Range, the strategy adopted by the Oregon Department of Forestry to achieve these goals relies on active management across the entire land base using an approach called "structure-based management" (Bordelon et al. 2000). Stand developmental stages (Oliver and Larson 1990) are achieved through silvicultural practices that use variable harvest rotation lengths. The goal for state forests in the Northwest is to have at least 50% of the landscape in "layered" and "older forest structure" types. Old-growth forests containing the full array of old-growth structures and processes are not a goal of the state plan. We assumed the Elliott State Forest in the south, the other large block of state land, includes conservation areas of existing mature and old-growth forests where no active management other than thinning will occur.

The goals of private industrial land owners are relatively homogeneous, and focus on high levels of timber production while complying with state and federally mandated environmental protections. The Oregon Forest Practices Act (FPA) (Oregon State Legislature 2001) is the only formal statement of biodiversity goals for this ownership. The management goals of nonindustrial private landowners are more difficult to characterize. Nonindustrial owners have shown a greater tendency toward partial cutting than industrial owners (Lettman and Campbell 1997). Sur-

TABLE 1. Extended.

| Management strategies |
| --- |
| 1) Reserves<br>2) Matrix management†<br>3) Green-tree retention<br>4) Stream buffers<br>5) Adaptive Management Areas‡ |
| Same as above but with different matrix prescriptions |
| 1) "Structure-based" management§<br>2) Habitat Conservation Plans¶ |
| |
| 1) Limited retention of individual trees<br>2) Limited stream-side protection for fish-bearing streams |
| Minimums are same as above but with greater tendency to use partial harvesting |

veys indicate that timber production is a common goal for many of these owners, but other objectives, including biodiversity, recreation, and passive management, are also common across this diverse group (Lettman and Campbell 1997, Kline et al. 2000). Consequently, the state FPA is the only legal representation in our analysis of the goals of the State of Oregon for this ownership. The goal of the FPA is to "encourage economically efficient forest practices that ensure the continuous growing and harvesting of forest tree species ... consistent with sound management of soil, air, water, fish and wildlife resources ... to ensure the continuous benefits of those resources for future generations of Oregonians." The explicit biodiversity protections in the FPA include complex rules for limiting timber harvesting within 3 to 30 m of fish-bearing streams and requirements for retention on the average hectare of five snags or green trees at least 28 cm dbh and 9 m tall (Oregon Forest Resources Institute 2002).

## APPROACH

The CLAMS approach has been previously described in some detail (Spies et al. 2002*a*, Spies and Johnson 2003, Bettinger et al. 2005), so we provide only a summary here. The general approach is to spatially project landscape change under the policies of different forest owners and then to use biodiversity and socioeconomic indicators to evaluate some of the effects of these changes. The overall modeling approach consists of a set of spatially linked models and databases that represent a variety of patterns and processes. Initial forest conditions are based on a spatially explicit model of initial (1996) vegetation conditions estimated from a gradient nearest neighbor (GNN) approach that incorporates Landsat imagery, forest inventory plots, and GIS (Ohmann and Gregory 2002). Land use changes are simulated using a spatial model that projects changes in building densities as a result of population growth and land use zoning and converts those densities into wildland forest, rural residential, and urban land-use classes (Kline et al. 2003).

A spatial forest landscape management and policy simulator (LAMPS; Bettinger and Johnson 2003, Johnson et al. 2007*a*) projects changes in forest conditions resulting from management action and forest succession. LAMPS simulates harvesting and partial cutting of forest stands and regrowth on a five-year time step for 100 years at a spatial resolution of about 0.16 ha. The simulations are primarily deterministic, but some fine-scale stochastic elements (e.g., small natural patch disturbances, assignment of harvest location) are included to incorporate uncertainty and heterogeneity at fine scales. Land management allocations, timber volume targets, and spatial constraints on harvesting are simulated for the different owners within the province. Stand growth and forest succession models are used to project forest structure and compositional changes. Outputs from LAMPS are spatially explicit lists of live and dead forest stand structure and composition over time and harvest area and volumes by type of management practice.

Biodiversity responses to forest conditions are simulated by using a variety of measures including habitat suitability models and forest stand and landscape structure indices (McComb et al. 2002, Burnett et al. 2007, Spies et al. 2007). Socioeconomic responses are characterized based on timber volume production estimates and job multipliers (Johnson et al. 2007*a*) and willingness-to-pay models (Garber-Yonts et al. 2004).

We engaged stakeholders throughout the process of developing our models and conducting assessments. We held periodic meetings with key groups representing the major landowners to explain our approach and receive feedback. We especially relied on a Policy Advisory Board of the Oregon Department of Forestry and the Oregon Forest Industries Council to advise us on policy questions to address, the quality of our databases, and modeling assumptions. The purpose of the project, however, was not to reach a decision or consensus regarding future policies for the Coast Range, but rather, to provide a framework for evaluating current and alternative policies across multiple ownerships.

Three possible policies were considered: the current policy as practiced by landowners and two alternatives. The alternative policies, selected after consultations with the Policy Advisory Board of the Oregon Department of Forestry, addressed stand-level activities of either retaining large trees following timber harvest or thinning young stands to promote structural diversity. This overview paper focuses primarily on results from projecting current policy.

## KEY FINDINGS

Under current policy, the status and trends of key indicators of biodiversity and socioeconomic conditions were variable and also differed among ownerships (Figs.

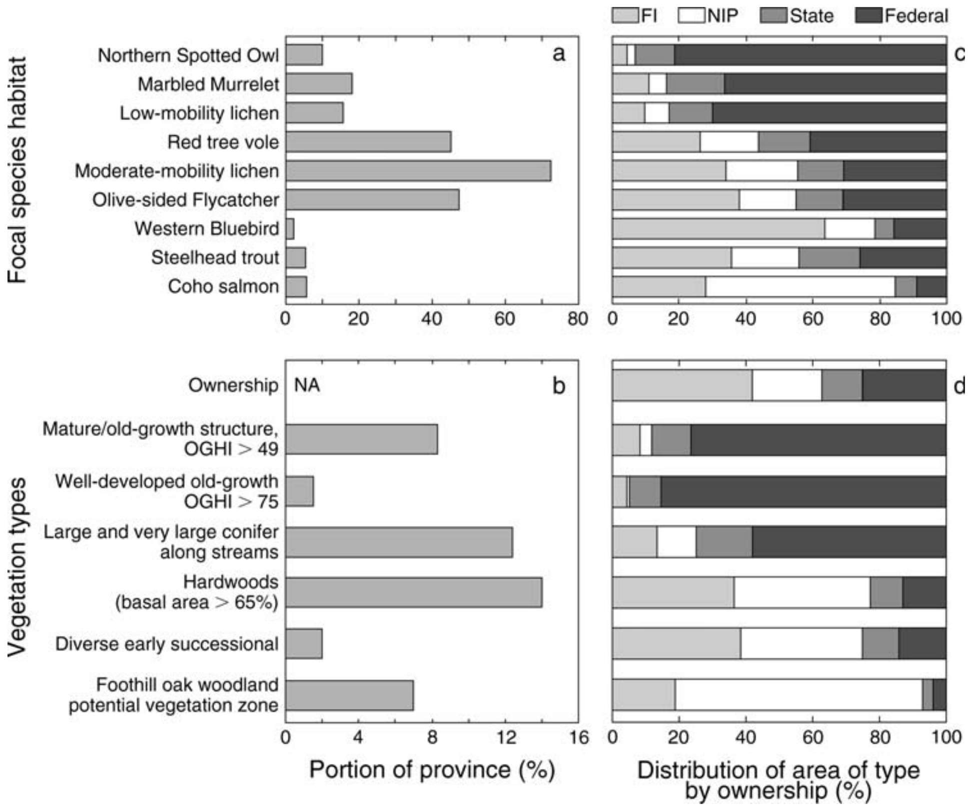


FIG. 2. Percentage of Coast Range in simulation year 0 in (a) habitat of selected focal species and (b) selected vegetation types, and (c, d) distribution of the areas of those measures by ownership classes. Distribution of ownership is shown for context in (d). Ownership abbreviations are the same as in Fig. 1 except that federal applies to both U.S. Forest Service and Bureau of Land Management lands. Definitions of focal species habitat for terrestrial animals and plants are described in Spies et al. (2007) and for salmonid species in Burnett et al. (2007). OGHI is an old-growth forest structure index that ranges from 0 to 100 (Ohmann et al. 2007), and diverse early-successional is vegetation with <40% canopy cover and occurrence of remnant live trees (Spies et al. 2007). Large and very large conifers are stands with quadratic mean diameters >50 cm (Spies et al. 2007), and foothill oak woodlands are areas that have potential to develop an oak vegetation type (Ohmann et al. 2007). "Large and very large conifers along streams" refers to the percentage of streamside covered by this forest cover class (Burnett et al. 2007).

2–4). The region is currently dominated by conifer forests, with about 14% of the area in ecologically important hardwood forests. Older conifer forests and habitats for associated species comprised a small percentage of the province (2%) in the mid 1990s, with most older forest occurring on federal lands (Ohmann et al. 2007; Fig. 2). In the simulation, old forest structure and habitat for species that prefer older forests strongly increased because of policies on federal lands and state forest lands (Figs. 3 and 4). Despite the increase, the amount of old forest did not reach a level that may have occurred in the last 1000 years under the historical range of variation. The area of hardwood forests is projected to strongly decline, as practices on private lands promote young conifer stands and practices on federal lands promote old-growth conifer forest development. Habitat for the Western Bluebird (*Sialia mexicana*), a species associated with open, diverse, early-seral conditions (tree canopy cover <20%, with remnant large trees and snags), is also projected to decline overall by 50%, with the decline found on all ownerships except state forest lands. Similarly, habitat for the Olive-sided Flycatcher (*Contopus cooperi*), a species associated with edges and relatively open canopies, is projected to decline 23% on federal ownerships. Potential oak woodland habitat occurs predominantly on private lands where there is no formal conservation policy for this forest type. We did not simulate oak forest succession in oak woodlands; however, simulations of land use change indicated that almost 22% of the potential oak woodland area would be lost to development.

Streams with the highest intrinsic potential to provide juvenile rearing habitat (based primarily on geomorphic characteristics) for coho salmon and steelhead (*O. mykiss*) are differentiated by ownership (Burnett et al. 2007). Most high intrinsic potential habitats for coho occur in lowland streams on private forest and non-forest lands, but habitats for steelhead are the steeper streams on federal and private industrial forest lands (Fig. 2). Although salmon habitat models that include vegetation are still under development, we could

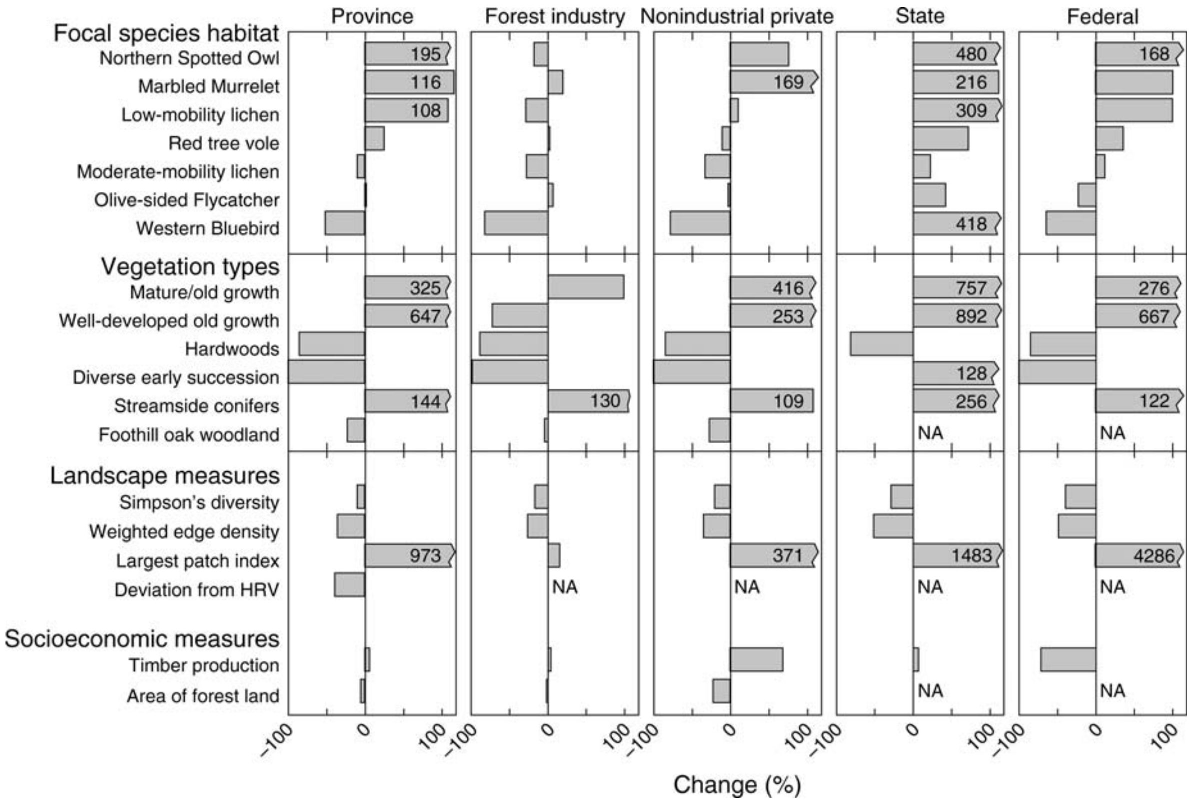


FIG. 3. Relative change in selected ecological and socioeconomic measures over a 100-year simulation for the Oregon Coast Range and by ownership classes within the province. Numbers indicate relative change percentages that exceed 100; NA, not applicable. Definitions of focal species habitat and vegetation types are the same as in Fig. 2. Landscape measures are described in Spies et al. (2007). Deviation from historical range of variation (HRV) is mean deviation (%) of forest age classes from the expected distribution of either the high or low end of the range of values under the historical disturbance regime (Spies et al. 2007). Timber production is change (%) in harvested volume ($m^3$/yr) (Johnson et al. 2007*a*) between the first and last period of the simulation, and forest land is defined as having a housing density low enough to permit forest land use practices (Johnson et al. 2007*a*).

estimate trends for an important component of that habitat, large conifer trees, which create habitat diversity when they fall into streams. The amount of riparian area with large and very large conifer trees is projected to increase significantly on all forest ownerships (Figs. 3 and 4), although these estimates should be considered an upper bound (Johnson et al. 2007*a*).

Trends in landscape measures of forest condition suggest that current policies will lead to a decline in edge and patch type diversity on all ownerships, especially federal lands (Fig. 3) (Spies et al. 2007). Large, continuous blocks of forest are likely to increase, mainly on Forest Service and state lands. The extremely large relative increases in this patch size metric probably results from a high sensitivity to the heterogeneity of 30-m pixels in the early simulation periods.

The area of all forest land that is expected to be lost to development as a result of population growth and land use zoning is relatively small (10%; Fig. 3), but substantial losses are projected to occur on nonindustrial private lands (35%) and locally near large cities and on gently sloping valley bottoms along the margins of the Coast Range (Johnson et al. 2007*a*). Forest management during the first few years of the simulation produces about $12.9 \times 10^6$ $m^3$/yr of wood, creating an annual revenue to landowners of ~\$500–600 million dollars (Johnson et al. 2007*a*). This level of production would produce about 20 000 jobs in the forest products industry using current job multipliers. The simulated long-term average timber production ranged from a high of 11.8 $m^3 \cdot ha^{-1} \cdot yr^{-1}$ on forest industry lands to a low of 0.5 $m^3 \cdot ha^{-1} \cdot yr^{-1}$ on federal lands. Nonindustrial private lands and state forest lands produced on average 8.8 and 3.8 $m^3 \cdot ha^{-1} \cdot yr^{-1}$, respectively, in our 100-year simulation. Our model was unable to fully implement the complex management plan for state forests. Consequently, we underestimate timber production on those lands by about 25–50% from what the state is currently planning. Timber production for the Coast Range is projected to remain relatively close to recent levels: enough volume is present to maintain harvest at the current rates. However, production trends vary by ownership class with declines on federal lands and some increased production from private lands. The projected increase in timber production from nonindustrial private lands near the end of the simulation is probably a result

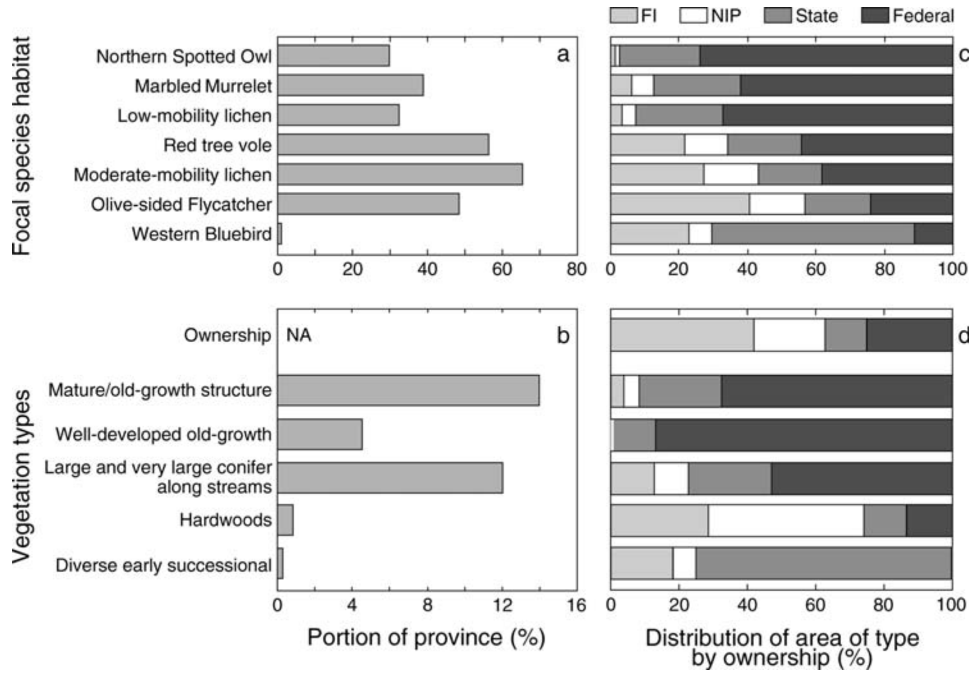


FIG. 4. Percentage of Coast Range in simulation year 100 in (a) habitat of selected focal species and (b) selected vegetation types, and (c, d) distribution of the areas of those measures by ownership classes. Distribution of ownership is shown for context in (d). Definitions of focal species habitat and vegetation types are the same as in Fig. 2.

of several factors including rotation age and decreased proportion of hardwoods (Johnson et al. 2007*a*). The decline in timber outputs from federal lands is part of a long-term trend that occurs because most timber production comes from thinning young plantations to enhance diversity, a practice that is currently allowed only until plantations reach 80 years of age.

## DISCUSSION

### *Multi-ownership perspective*

The relatively uncoordinated development of biodiversity policies in the Coast Range will generally produce a diversity of forest conditons (see Plate 1). Recent changes in federal land management are projected to reverse the 150-year declining trend in area of habitats associated with large, old conifers. Changes in public and private land management could potentially double the area of streamsides with large conifers. However, some elements of forest structure and composition are expected to decline under current policies, including overall seral-stage diversity, hardwoods, and open, structurally diverse early successional stages. Species whose habitat could decline as a result include the Western Bluebird and lichens and other species that reach peak abundance in early-seral or mid-seral stages. Declines might be greater for other less mobile species of plants and animals associated with these vegetation types. The multi-ownership perspective also reveals that ecosystem types on the margins of the Coast Range—oak woodlands and low-gradient streams—are not well protected in the current mix of individual conservation programs.

The spatial pattern of ownerships substantially influences trends in our indicators of biological diversity. The juxtaposition of highly contrasting policies and practices leads to major changes in edge and interior forest conditions. While vegetation patterns show increasing contrast among ownerships (Spies et al. 2007), the total amount of edge habitat actually declines because dominant uses by major landowner types are aggregated in large blocks. The concentration of public lands on upper slopes and private lands on lower slopes and valley bottoms (Burnett et al. 2007) may influence the movement of landslides and debris flows, affecting habitat quality for salmonids; steeper, upper slopes are more likely to be sources of landslides and debris flows than lower slopes (Sidle et al. 1985, Montgomery and Dietrich 1994). Landslides originating near small headwater streams on federal lands, where riparian forests are protected from harvest, could carry large wood, and important component of aquatic habitat complexity, into lower parts of the drainage network that may be in private ownership, where streamside protection is much more limited (e.g., agricultural lands). Such transfers from streams on public lands may help maintain aquatic habitat diversity on private lands. On the other hand, salmon returning to streams high in watersheds on public lands must pass through streams on agricultural and developed lands where habitats and water quality may be unsuitable. The checkerboard landscapes—the alternating sections of

PLATE 1. A mixed-ownership landscape in the central Coast Range of Oregon, looking north across the Umpqua river. The area contains a mixture of recent clearcuts and conifer plantations on industrial forest land, plantations and old conifer forests on USDI Bureau of Land Management land, and agricultural land use on non-industrial private lands along the river. Note the hardwood forest along the stream that enters into the river on the right side of the image. Also note the small patch of old-growth conifer forest (dark patch) upslope from the riparian hardwood forest. The image illustrates the contrasting forest conditions and spatial patterns that can result from a highly contrasting mix of forest management policies and ownerships. Photo credit: T. Spies.

BLM and private lands (Fig. 1)—that contain highly contrasting forest conditions, are potentially susceptible to the spread of pathogens, invasive species, and fire from one ownership to another. However, this concern was beyond the scope of this study.

Although current forest policies were largely developed independently, some plans take ownership differences into account. For example, it is generally assumed that the high levels of protection for late-successional habitats and species on federal lands reduce the responsibility of private forest-land owners for recovering listed species on their lands. Some evidence for this can be found in the Habitat Conservation Plan (HCP) (Weyerhauser 1994) that was developed for the 85 000-ha Weyerhaeuser Millcoma tree farm, which lies south of the Elliott State Forest and west and north of BLM lands (Fig. 1). Under this HCP, the timber company is granted an "Incidental Take Permit," allowing it to log some of the remaining nesting habitat for the Northern Spotted Owl on its land in exchange for improving dispersal habitat for the owl between adjacent blocks of nesting habitat on public lands. Logging of the remaining nesting habitat was deferred for at least 20 years until more owl habitat develops on adjacent public lands. The federal lands also bear the responsibility of habitat recovery for coho. However, unlike in the case of the owl, the federal lands do not contain much of the high potential coho habitat, which occurs primarily on nonindustrial private forest, agriculture, and developed lands (Burnett et al. 2007). Consequently, the conservation strategy for coho does not focus on the most ecologically suitable part of the stream network.

Timber production was one of our main measures of socioeconomic effects. The decline in federal harvests that we simulated is on top of the major decline in federal timber production that occurred in early 1990s, when harvesting of mature and old-growth forests on federal lands was stopped by court injunctions. We did not model timber production interactions among owners; our timber-harvest model does not include price-related feedbacks that might come from variation in timber supply within the Coast Range. However, harvest levels have not interacted strongly among ownerships in recent years. Timber production on private industrial lands did not respond to the major spike in timber prices that occurred in the early 1990s as timber output fell by more than 75% on federal lands in the region (Haynes et al. 2003). Timber production from nonindustrial private lands did increase for a few years until sinking to previous levels. Several factors contributed to the lack of increase in harvest on private lands, including an economic recession in Asia that reduced the export market, the industry's need to maintain an even flow of wood supplies to its mills, a shortage of mature forest on industry land, and domestic prices that decreased fairly rapidly from their peak.

Our other main measure of socioeconomic effects was the value that people place on the amount of old-growth forest in the Coast Range. In addition to the direct benefits of increasing the area of habitat for the two listed bird species, the projected increase in percentage of old-growth forest in the Province to over 10% would have high value to the public. A survey of Oregonians suggested that they would be willing to pay over 300 million dollars a year to increase the amount of old-growth forest to about one-third of the Coast Range (Garber-Yonts et al. 2004).

### *Within-ownership perspectives*

The overall condition of biodiversity in the province is outside the purview of many federal and state institutions and policies, and thus any gaps or deficiencies in biodiversity protection will probably be addressed only in relation to policy problems within ownerships. Although the Oregon FPA applies to both state and private lands, it is too general to guide broad-scale conservation. All lands are subject to federal regulations for implementing the Endangered Species Act for the Northern Spotted Owl, the Marbled Murrelet, and coho salmon (recently delisted but still a candidate species). However, recovery planning for these species does not take a comprehensive view of biological diversity. The Clean Water Act applies to all ownerships and may be implemented in a way to help sustain aquatic biodiversity. Given the lack of overarching frameworks and institutions for forest lands, changes in policies to protect biodiversity will most likely come first from within individual ownerships. Consequently, it is important to examine the efficacy of current policies to meet objectives within ownerships for clues to where changes in forests policy might occur.

On federal lands, increases in old-growth, streamside conifers, and habitat for associated species are consistent with the NWFP. Trends in other indicators may not be consistent with federal policies. These include (1) uneven flow and decline in production of timber and (2) decline in seral stage diversity. Timber harvests are projected to decline (Johnson 2007*a*) as stands become too old (80 years) for thinning and the flow of timber from restoration thinning decreases. This declining production could be inconsistent with federal policies that direct the agencies to provide a sustainable flow of timber to support local communities. In the second case, the decline in seral stage diversity and early successional vegetation types on federal lands may be inconsistent with the diversity clause of the NFMA. The decline might also negatively impact the northern spotted owl in the southern part of its range (including the southern part of the Coast Range) where its fitness is actually higher in a landscape mosaic of ecologically diverse early seral vegetation and older forests, than in landscapes that are dominated primarily by older forest (Franklin et al. 2000*a*).

Our analysis of state lands, where the goal is to achieve a relatively even mix of forest uses with a minimum of zoning, did not reveal any major inconsistencies with current policy. All of the focal species and many of the vegetation and landscape measures were projected to increase, although hardwoods did decline. At the same time mean annual timber production was higher than on the reserve-dominated federal lands but lower than on high-yield forest industry lands. These outcomes appear consistent with the goals of the state forests, although these goals are only generally defined and are open to considerable interpretation as continued political debates in Oregon indicate. The generally positive story on the state lands should be qualified in three ways. First, most of the northern blocks of state lands are currently young, having established following large fires in the mid 20th century. Consequently, timber production goals can be met without harvesting existing old-growth forests and the relative amount of late-successional habitat increases dramatically because little older forest currently exists there. Second, as mentioned above, the simulation probably underestimates the volume cut and overestimates the amounts of larger diameter forests compared to how the State of Oregon is currently expected to manage those lands. Third, because the state policy uses extended rotations (up to ~150 years) and because the forest is relatively young, little of the oldest, most complex, forest is expected to develop on these lands. The state approach has been criticized for not including reserves (Franklin et al. 2000*b*), because it fails to provide for the oldest and most complex end of the old-forest spectrum and it assumes that ecological goals can be provided entirely through management. To adequately evaluate differences between a long-rotation strategy and a reserve strategy in this young forest landscape, any simulations would need to model forest dynamics for at least 200 years.

The high rates of timber production on forest industry lands, are of course, consistent with owner's objectives and state policies. Many terrestrial and aquatic plant and animal species would find habitat within the relatively young managed forests that dominate these lands (Johnson and O'Neil 2001). For example, our analyses indicated that forest industry lands currently contribute a large portion of the habitat for several focal species (Fig. 2). The habitat for one of those species, the western bluebird, currently occurs on forest industry lands in greater proportion than the proportion of this ownership in the study area. Projected increases in biodiversity measures—including Marbled Murrelet habitat, area of old growth structure, and proportion of stream sides with large conifers—occurred largely because recent streamside protection rules enabled large conifers to develop along the 5–7% of these lands that are in streamside buffers. The relatively high rates of increase resulted because little large conifer forest presently exists along streams on these lands. The decline in early-successional measures (e.g., Bluebird habitat) may be surprising because short rotations might be expected to produce a high proportion of open canopy conditions. However, we assumed that forest management on these lands will intensify over time, decreasing the period required for plantations to reach canopy closure, increasing the uniformity of plantations, and decreasing the occurrence of remnant trees in the open, early-successional stage. Although some light-demanding early-successional species will find habitats here for short periods before conifer canopies close (Halpern and Spies 1995), the overall ecological diversity of these early-successional types is expected to decline under current policies.

The picture on the nonindustrial private lands is generally similar to that of forest industry lands, but management intensity is somewhat lower and some ecological conditions differ. Nonindustrial private lands currently contain a large percentage of the region's hardwoods and diverse early successional vegetation, which both occur in greater proportion than expected based on the area of the ownership. Although we project declines, these vegetation types are still expected to be more common than on industry lands. A primary biodiversity value of these lands lies in their low topographic positions and distinctive climate along the margins of the Coast Range. These lands contain most of the potential oak woodlands, along with a large portion of the high intrinsic potential habitat for coho salmon, which occurs in low-gradient rivers. Currently, privately owned lands have no conservation policy for these important terrestrial and aquatic ecosystem types.

### *Alternative practices*

Although the largely uncoordinated development of forest policies meets several important biodiversity goals, some gaps remain in biodiversity protection that could be addressed with more coordinated management. For example, if green tree retention were increased on private lands where rates of canopy-opening disturbance are relatively high, more structural diversity of early-successional forests would be produced and habitat for species such as the western bluebird would increase (Spies et al. 2007). However, the costs would probably dissuade many landowners from providing high levels of retention. Another option for producing diverse early-successional stages and hardwoods is to create them on federal lands by actively managing some of the existing plantations. This approach, which would have to be integrated with the NWFP old growth strategy, could also provide a modest but sustainable flow of timber products. Currently, little or no early-successional forests is planned on Forest Service lands because there is little matrix allocation; on BLM lands, where matrix lands are more common, the rate of early successional habitat creation on BLM matrix lands has been much lower than allowed for in the NWFP (Moeur et al. 2005). A goal of creating early-successional habitat is challenging because it is difficult to estimate how much, if any, is needed beyond what will inevitably be produced through natural disturbances. In landscapes such as the Coast Range, where large fires and windstorms are relatively infrequent, many decades may pass without a large disturbance and when one does occur, it may not happen on federal ownerships where post-disturbance management would be most likely to promote diverse early-successional conditions.

Alternative policies could also be crafted for riparian zones. For example, riparian protections similar to those for forested areas could be extended to streams within agricultural and developed lands that provide important habitat for coho salmon and passage for steelhead. Another example is related to riparian policy for small, headwater streams. Forest clearing near these streams can affect local susceptibility to debris-flow initiation, distances debris flows travel, and types and amounts of materials delivered to fish-bearing streams (Montgomery et al. 2000, Lancaster et al. 2001, May 2002). At present, logging along headwater streams is prohibited on all federal lands but allowed on all private lands. Headwater streams are numerous and differ in susceptibility to debris-flow effects (Benda and Cundy 1990, Fannin and Rollerson 1993, May 2002), but it is now possible to identify the relatively small subset with high probabilities of delivering debris flows to fish-bearing streams (Miller and Burnett, *in press*; D. Miller and K. Burnett, *unpublished data*). Thus, riparian protection can be targeted at headwater streams that are debris-flow sources, efficiently maintaining ecosystem function while maintaining options for management of the entire stream network.

### *Limitations and uncertainties*

Our landscape projection was limited in several ways, especially by excluding large stand-replacement fire and effects of climate change. Had these been included, our conclusions might be different. Historical fires in this province were large (mean size of over 70 000 ha) and infrequent (Wimberly 2002); consequently, it is possible for a hundred years to pass with little or no fire. However, if one or more large fires were included in our simulation, thousands of hectares of forest could have burned, creating large patches of early-successional stages, depending on the management response.

Climate change could also affect our conclusions. The possible effects of climate change in the Pacific Northwest Region, range from forest decline in response to higher moisture stress to initial increases in the forest area as a result of increased moisture (Joint Institute for the Study of the Atmosphere and Ocean 1999). In the Coast Range, the most likely areas to be affected would be the drier eastern valley margins, where moisture stress and increased probability of fire could reduce forest growth and shift forests toward earlier successional conditions.

Finally, we were able to examine only one land-use-change scenario. Other scenarios are possible. For example, land exchanges between public and private lands may occur, which would alter management practices in some areas. However, these have been typically small in recent years and the industrial land-ownership base has been relatively stable, although ownership patterns within the class of industrial owners has been dynamic. The current shift in ownership of industrial forest lands from timber products companies with mills to timber management investment corporations with investment objectives has unknown impacts on how those lands are managed in the long-term. Continued or increased expansion of urban and rural residential development could lead to further declines in forest management intensity, with uncertain effects on biodiversity.

## Conclusions

Despite its limitations, we believe that the study provides valuable insights about approaches to bioregional assessments, policy effects in multi-ownership landscapes, and the promises and pitfalls of anticipatory assessments:

1) Using multiple types of indicators, including those representing habitat for focal species and forest structure and dynamics, can provide complementary information and lead to a more robust assessment.

2) It is useful to include both stand- and landscape-scale simulations in a scaling-up process; otherwise, estimates of the effects of stand-level practices at broad scales are just guesswork.

3) Recently enacted policies can lead to major changes in measures of forest biodiversity in this province. Several of these changes are consistent with goals of these policies: e.g., increases in the area of old-growth forests, habitat for associated species, the area of large conifers along streams, and patch sizes. Some of the changes appear inconsistent with current biodiversity policies and concerns: e.g., decreases in the area of Western Bluebird habitat, area of hardwoods, area of structurally diverse early-seral vegetation, and diversity of vegetation within ownerships.

4) Biodiversity policies in this multi-ownership region have two major shortcomings: First, with the exception of the federal lands, biodiversity policy goals are not stated explicitly enough to be used alone as benchmarks for measuring progress or success; stakeholders will have to be engaged to determine the acceptability of the biodiversity changes we identify. Second, no policies really address the entire province. Consequently, biodiversity patterns are dependent on the decisions of individual owners and vulnerable to unilateral changes in policies and practices.

Johnson et al. (2007*a*) point out that our attempt at conducting an anticipatory assessment and working with stakeholders to integrate science and policy was quite challenging. They further argue that, despite the promise of anticipatory assessments, the role and contribution of this type of assessment in policy debates is uncertain. Policy makers and stakeholders have found it difficult or uninteresting to think at broad spatial and temporal scales and policy makers do not necessarily want scientists to point out problems with the status quo.

Although we have learned much from this major effort, in many ways we have just begun to address one of the most fundamental questions in forest ecosystem management: What are the consequences of different spatial arrangements of forest management practices, and how do they vary with spatial and temporal scale? We hope that it does not always require a crisis for research to address this important question.

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