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Contributed Paper

Evaluating Areas of High Conservation Value in Western Oregon with a Decision-Support Model

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Abstract: *The Northwest Forest Plan was implemented in 1994 to protect habitat for species associated with old-growth forests, including Northern Spotted Owls (*Strix occidentailis caurina*) in Washington, Oregon, and northern California (U.S.A.). Nevertheless, 10-year monitoring data indicate mixed success in meeting the ecological goals of the plan. We used the ecosystem management decision-support model to evaluate terrestrial and aquatic habitats across the landscape on the basis of ecological objectives of the Northwest Forest Plan, which included maintenance of late-successional and old-growth forest, recovery, and maintenance of Pacific salmon (*Oncorhynchus *spp.), and viability of Northern Spotted Owls. Areas of the landscape that contained habitat characteristics that supported these objectives were considered of high conservation value. We used the model to evaluate ecological condition of each of the 36 ,180 township and range sections of the study area. Eighteen percent of the study area was identified as habitat of high conservation value. These areas were mostly on public lands. Many of the sections that contained habitat of exceptional conservation value were on Bureau of Land Management land that has been considered for management-plan revisions to increase timber harvests. The results of our model can be used to guide future land management in the Northwest Forest Plan area, and illustrate how decision-support models can help land managers develop strategies to better meet their goals.*

Keywords: decision-support model, EMDS, land management, Northwest Forest Plan

Evaluación de Áreas de Alto Valor de Conservación en el Occidente de Oregon Mediante un Modelo de Respaldo a la Toma de Decisiones

Resumen: *El Plan Forestal Noroccidental fue implementado en 1994 para proteger el hábitat para especies asociadas con bosques maduros, incluyendo* Strix occidentailis caurina *en Washington, Oregon y norte de California (E. U. A.). Sin embargo, datos de monitoreo durante 10 años indican éxito mixto en el logro de las metas ecológicas del plan. Utilizamos el modelo de respaldo a la toma de decisiones para el manejo de ecosistemas para evaluar hábitats terrestres y acuáticos en el paisaje con base en los objetivos ecológicos del Plan Forestal Noroccidentalm que incluían el mantenimiento del bosque maduro y en sucesión tardía, la recuperación y mantenimiento de salmón (*Oncorhynchus *spp.), y la viabilidad de* Strix occidentailis caurina*. Las áreas del paisaje que contenían características del hábitat que soportaron estos objetivos fueron considerados de alto valor de conservación. Utilizamos el modelo para evaluar la condición ecológica de cada uno de los 36 180 distritos y secciones del área de estudio. Dieciocho por ciento del área de estudio fue identificado como hábitat con alto valor de conservación. Estas áreas estaban principalmente en tierras públicas. Muchas de las secciones que contenían hábitat con valor excepcional de conservación estaban en tierras del Buró de Gestión de Tierras que han sido consideradas para revisión de los planes de manejo para incrementar la cosecha de madera. Los resultados de nuestro modelo pueden ser utilizados para guiar la gestión de tierras en el futuro en el área del Plan Forestal Noroccidental, y los modelos de respaldo a la toma de decisiones pueden ayudar al desarrollo de estrategias para mejorar el alcance de sus metas.*

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Palabras Clave: EMDS, manejo de tierras, modelo de respaldo a la toma de decisiones, Plan Forestal Noroccidental

Introduction

Since 1994 approximately 9.8 million ha of U.S. Department of Agriculture Forest Service (USFS) and Bureau of Land Management (BLM) lands within the range of the Northern Spotted Owl (*Strix occidentalis caurina*) have been managed under the Northwest Forest Plan (NWFP) to protect habitat for species associated with old-growth forests and to facilitate dispersal of these species across an intensively managed matrix (USDA 1994). Although triggered by the decline of the Spotted Owl, the NWFP also was meant to support the recovery and maintenance of Pacific salmon (*Oncorhynchus* spp.) and other sensitive aquatic species, maintain, or create functional connectivity of late-successional and old-growth forests (LSOG) on federal lands, and provide a predictable and sustainable timber harvest to support the economies of rural communities. To achieve these goals, the plan relied on an assortment of land-use allocations, including existing congressionally withdrawn lands and late-successional reserves (LSRs). Most timber harvests targeted the matrix lands outside these designations.

After 10 years of implementation of the 100-year NWFP, monitoring efforts reveal mixed success in meeting the ecological goals of the plan. Although watershed conditions have improved (Reeves et al. 2006) and LSOG habitat has increased by almost 2% (Moeur et al. 2005), Spotted Owls are declining more than expected in some areas (Lint 2005; Noon & Blakesley 2006) and Marbled Murrelets (*Brachyramphus marmoratus*), a threatened species dependent on old-growth forests for nesting, are experiencing low recruitment rates (Raphael 2006). In addition, the BLM recently approved major revisions to their management plans in western Oregon in response to lawsuits by the timber industry (BLM 2008). Although these plans are now suspended, the BLM lands compose about one-quarter of the NWFP area in western Oregon, so future plans could have a significant effect on ecological outcomes.

Traditional land-use planning has treated national forests and other public lands as self-contained units rather than viewing them as integrated parts of a larger landscape. The ecological goals of the NWFP may be better achieved if the contributions of federal lands to biodiversity conservation are evaluated in the context of the entire landscape (Thomas et al. 2006). We used a spatially explicit decision-support model to illustrate how to achieve this broader perspective. In the model, we included characteristics of the entire landscape in an evaluation of the ecological condition of the NWFP area in western Oregon. We based our choice of model parameters on the ecological objectives explicit in the NWFP and used the model results to identify areas of high conservation value (HCV). We also examined current and proposed management of these areas under the plan. The HCV concept emerged from a sustainable forestry concept known as high conservation-value forest (HCVF) developed by the Forest Stewardship Council and has become a valuable tool for a variety of uses, including land-use planning and forest management (Jennings et al. 2003).

Methods

Study Area

Oregon contains approximately 4 million ha or nearly 40% of the public lands managed under the NWFP, most of which (73%) is administered by the USFS. Our study area included the 7.7 million ha (all ownerships) within the Coos Bay, Eugene, Medford, Roseburg, and Salem BLM management districts. The majority of the study area (4.3 million ha) is privately owned. We chose this area rather than the entire NWFP because of availability of spatial data sets related to the western Oregon Plan Revisions (WOPR) of the BLM (BLM 2008) and because the agency was proposing sweeping changes to the NWFP. Within the study area, we used township and range sections (sections) as our unit of analysis to evaluate HCV habitat as defined by the ecological goals of the NWFP. We chose sections as opposed to other units (e.g., watersheds) because many public lands in western Oregon follow section boundaries. There were 36,180 sections in our landscape with an average size of 213 ha.

Our study area contained portions of four ecoregions as defined by Ricketts et al. (1999): central Pacific coastal forests, central and southern Cascades forests, Klamath-Siskiyou forests, and Willamette Valley forests. The forests of western Oregon are dominated by Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) (Franklin & Dyrness 1973). The Klamath-Siskiyou Forests ecoregion is recognized for its high conifer species richness (DellaSala et al. 1999), and Willamette Valley forests ecoregion is predominantly agricultural and urban with pockets of Douglas-fir and Oregon white oak (*Quercus garryana*).

Logic Model

We used the ecosystem management decision-support (EMDS) tool (Reynolds 1999) to develop our model. The decision rules were created in the NetWeaver knowledge-base system (Rules of Thumb, Northeast, Pennsylvania).

The NetWeaver system allows users to develop knowledge bases as logical frameworks for assessing complex ecological problems that involve the simultaneous analysis of multiple data sets. We present the formal logic structure as a topic outline (Table 1). Each attribute in a NetWeaver model represents a topic for which a proposition is evaluated with available data sets. Our selection of topics and the data sets we used to evaluate them stem from our interpretation of the ecological objectives of the NWFP. We defined terrestrial HCV areas as forest habitats that support Spotted Owls, Marbled Murrelets, and other species of interest on the basis of actual presence data or areas of intact LSOG habitat determined on the basis of analysis of vegetation data. Aquatic HCV habitat included stream and riparian areas that support the recovery and maintenance of salmon and other sensitive aquatic species as determined on the basis of stream characteristics (e.g., few dams, low slope, known to contain fish) or watershed condition (e.g., forested). Thus, the aquatic value topic in Table 1 evaluates the proposition that the section contains habitat that is of high value to aquatic organisms and therefore could promote recovery of salmon and other aquatic species.

The complete evaluation of overall HCV habitat in a section depends on two primary topics—aquatic value and terrestrial value—each of which contributes equally to the evaluation as indicated by the *or* operator (Table 1). The secondary topics of fish value and watershed value contribute incrementally to the evaluation of aquatic value as indicated by the *union* operator, which functions like an average such that low strength of evidence for one topic can be compensated for by strong evidence from the other. The same is true for forest value and terrestrial species value relative to terrestrial value. Elementary topics directly evaluate one or more geographic information system (GIS) data sets. For example, stream condition is evaluated by the incremental contribution (as indicated by the *union* operator) of four data inputs: road density, slope, kilometers of water-quality limited streams, and dams. Thus, lower values for each of the data inputs indicate higher conservation value for stream condition. In contrast, the elementary topic of old forest is defined only by the percentage of LSOG in the section. The model represents one of many possible logical configurations that could be easily adapted to test other propositions or incorporate new information.

We used fuzzy logic to evaluate each topic's proposition on the basis of data inputs. We assigned reference values for each datum to define critical values that indicate no support or full support for the proposition (Table 1). The reference values were based on threshold values in the literature when available or were 1 SD above and below the mean value of the datum. For example, the datum of "RDDENS" under the elementary topic of "stream condition" had reference values of 0 and 3.23. Thus, sections with road density >3.23 km/km^2 provided no evidence for the proposition of "good stream condition," whereas sections containing a road density of 0 km/km^2 provided full evidence for the proposition. Sections in which road densities fell between the reference values provided partial support for the proposition. Fuzzy logic arguments are useful in ecological modeling, where absolute thresholds are rarely known, because they allow users to reason with incomplete information. The knowledge base can be easily altered to reflect different reference values as more information becomes available or to test different management scenarios.

We evaluated all sections in our study area in EMDS, which integrates the NetWeaver knowledge-based reasoning with the spatial data sets (Table 1) into a GIS (ArcMap 9.0) environment that shows the results of each intermediate topic that leads to the model topic of HCV. The analysis resulted in evaluations of each of the 18 model topics for each section in our NetWeaver knowledge base that indicated the strength of evidence in support of the proposition of each topic as a value ranging from -1 (no support) to 1 (full support). Thus, propositions with levels of support close to 1 indicate they are well-supported by the underlying data.

Data Sources

The majority of the spatial data we used came from the BLM WOPR project (www.blm.gov/or/plans/wopr/data/index.php). The remainder were obtained from other public sources (e.g., Oregon Natural Heritage Program) or derived from publicly available data. Forest fragmentation indices were calculated with Fragstats software (McGarigal et al. 2002). For analyses of protected areas, we used the Protected Areas Database (DellaSala et al. 2001) to determine the protection level of each section on the basis of Gap Analysis Program (GAP) codes (Gap Analysis Program 2000). We considered that GAP codes 1 and 2 indicated strict and moderate protection levels and GAP code 3 indicated areas that were minimally protected from human disturbance.

Results

Nearly 20% of the study area showed full or strong support for the proposition of HCV and 40% showed moderate support. Support for the proposition was highest along the Cascades Range in the eastern portion of our study area and was strong to moderately high throughout much of the Coast Range (Fig. 1). Most sections in the Willamette Valley (north-central portion of our study area) showed low, very low, or no support. In general, these differences correlated strongly with land ownership. The majority (87%) of the study area that contained HCV sections was on public land, whereas 93% of areas with no HCV sections were on private land.

Table 1. Logic outline for evaluation of areas of high conservation value (HCV).

Model topic	Primary topic	Secondary topic	Elementary topic	Proposition[a]	Data inputs[b]	Reference values[c] no evidence	Reference values[c] full evidence
HCV (*or*)[d]				overall conservation value is high			
	aquatic value (*union*)			value to aquatic organisms and habitat is high			
		fish value (*union*)		section has streams that support fish			
			fish-bearing streams	contains a high percentage of fish-bearing streams	FISH_KM	0.0	0.32
			salmon value (*or*)	contains watersheds identified as crucial to at-risk fish species	PCTKEY COHO	0.0 0.0	50.0 0.41
		watershed value (*union*)		watersheds are in good condition for supporting aquatic organisms			
			cover quality (*union*)	forest cover is conducive to good watershed condition	PCT_NF LSOG	54.0 0.0	0.0 100.0
			stream condition (*union*)	streams are in good condition and conducive to good watershed condition	RDDENS SLOPE 303D DAMS	3.23 25.0 1.34 7.0	0.0 8.0 0.0 0.0
	terrestrial value (*union*)			value to terrestrial organisms and habitats is high			
		forest value (*union*)		contains intact, older forests of high conservation value			
			old forest	contains old forest	LSOG	0.0	100.0
			LSOG[e] intactness (*union*)	LSOG habitat is intact with good connectivity	MNN NP TCAI	0.0 2.0 3.24	208.0 5.0 0.0
		terrestrial spp. value (*or*)		supports listed terrestrial species or species of concern			
			owl suitability (*or*)	contains Northern Spotted Owls	NSO_PAIR OWL_PRES	0.0 0.0	20.0 1.0
			murrelet suitability (*or*)	contains Marbled Murrelets	MUR_PRES	0.0	1.0
			survey and manage species	contains survey and manage species	SM_SPP	0.0	4.0

[a] *Each proposition evaluates a set of premises or data relative to a specific landscape unit (i.e., section).*
[b] *Definitions of data items: FISH_KM, total kilometers of fish-bearing streams in section; PCTKEY, percentage of section that is a key watershed; COHO, total kilometers of coho critical habitat in section; PCT_NF, percentage of section that is nonforest; LSOG, percentage of section that is LSOG (late-successional and old-growth forest); RDDENS, road density (km/km^2); SLOPE, average slope in section; 303D, total kilometers of water-quality-limited streams in section; DAMS, total number of fish barriers within the fifth field watershed; MNN, index of distance to nearest LSOG patch; NP, number of patches of LSOG; TCAI, fragmentation index for amount of interior forest habitat; NSO_PAIR, number of Spotted Owl pairs nesting in section; OWL_PRES, Spotted Owls observed in section; MUR_PRES, murrelets observed in section; SM_SPP, number of survey and manage species observed in section.*
[c] *Reference values define critical values for the fuzzy logic function of the associated elementary topic. An observed value for the datum that falls between the threshold numbers evaluates to partial support for the associated proposition.*
[d] *Terms in parentheses indicate the logic operator used to evaluate the propositions under a topic. For example, conservation value is evaluated with the or operator indicating that aquatic value and terrestrial value contribute equally to conservation value. Aquatic value is evaluated as the union (similar to an average) of fish value and watershed value.*
[e] *Late-successional and old-growth forest.*

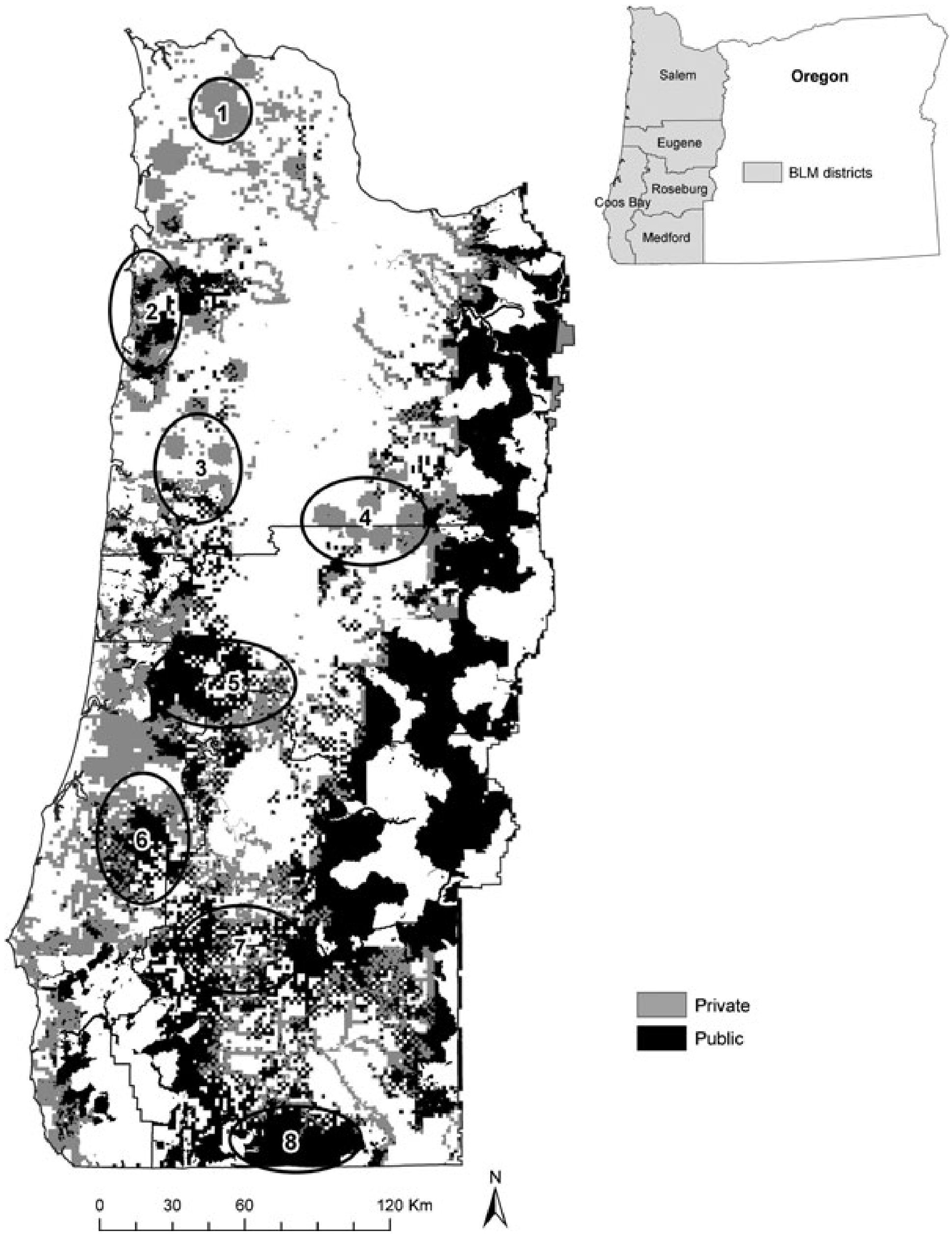

Figure 1. Sections of the study area in Oregon that show moderate to full support for the proposition of high conservation value and that are minimally (GAP 3) or unprotected in existing reserves.

The evaluation of aquatic value was composed of the partial evaluations (*union*) of fish value and watershed value (Fig. 2). Overall there was little support for the proposition of high aquatic value; only 4% of the study area showed full or strong support of high aquatic value. Sections that showed moderate or full support for the proposition were mostly in the southern portion of the study area, and there was another hotspot in the northeastern portion of the Cascade Range. Most of these sections were located on public land. There was mixed support in the northwest portion of the study area and very low support in the Willamette Valley. Sections that contained high fish-value habitat occupied 13% of the study area and exerted significant influence on the final aquatic-value results. These high-value streams were primarily located in the southern portion of the study area, but there were a few scattered in the northern portion.

The evaluation of terrestrial value was composed of partial evaluations of forest value and terrestrial species value (Fig. 2). In general, the terrestrial value evaluation showed sections displaying conditions favorable to LSOG-associated species including Spotted Owls and Marbled Murrelets in the Cascades Range and in much of the Coast Range. There was no support for the proposition of high terrestrial value in the Willamette Valley (which is largely treeless) or for portions of the Coast Range. Overall, 17% of the study area contained high terrestrial value habitat and 35% was of moderate terrestrial value. These results were heavily influenced by the topic of terrestrial species value—47% of the study area showed strong to full

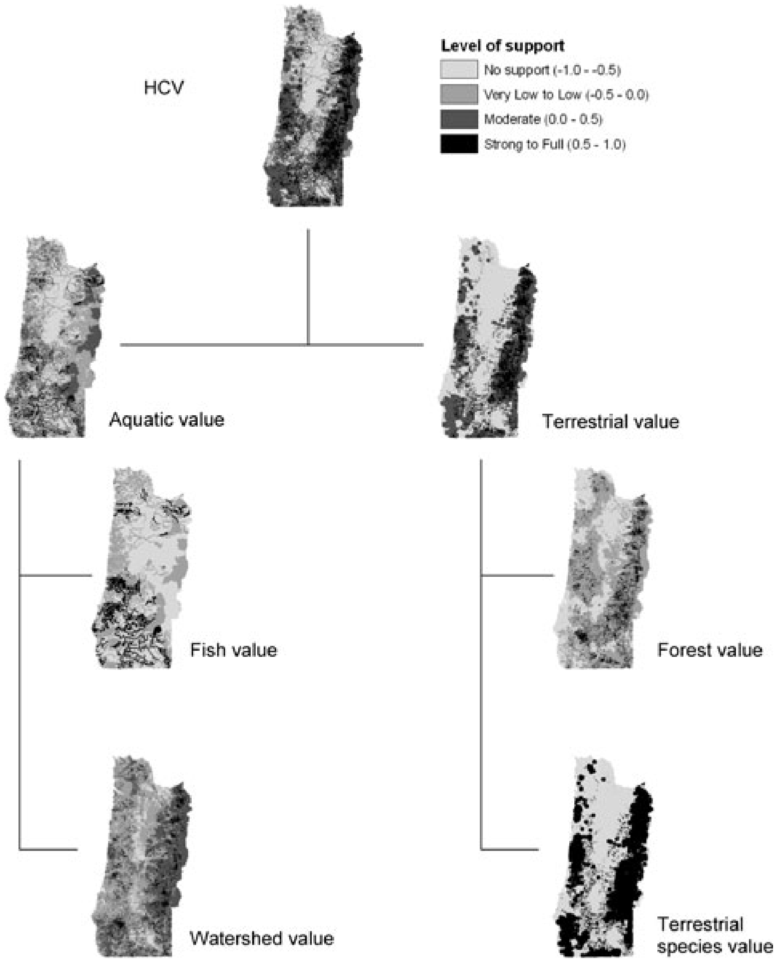

Figure 2. In a model to evaluate terrestrial and aquatic habitats across Oregon, maps show the composite of intermediate model results that indicate the contribution of each factor to final model results.

support for this proposition. Thus, terrestrial species value compensated for the relatively low support for the proposition of high forest value.

Because many of the sections were located on publicly owned land, some are protected from development activities in various types of reserves (e.g., parks, wilderness) (Fig. 1). Of the areas that showed full or strong support for the proposition of HCV, 37% were strictly or moderately protected (GAP 1 or 2) in wilderness areas, national parks, or LSRs, whereas 50% were in minimally protected (GAP 3) areas, such as national forests, which are subject to extractive uses. For areas of moderate conservation value, 21% were located in moderately or strictly protected areas and 34% were minimally protected. There was little protection (8% strict or moderate, 19% minimal) for sections that showed very low or no support for the proposition of HCV.

Discussion

Management Implications

Ten years after implementation of the NWFP, monitoring data revealed that not all ecological objectives of the plan were being met. Researchers were particularly concerned about viability of Spotted Owls and Marbled Murrelets that rely on LSOG habitat for foraging and nesting (Noon & McKelvey 1996; McShane et al. 2004; Marcot & Molina 2006). Although Barred Owl (*Strix varia*) intrusions may also be a factor in Spotted Owl declines, their effects on these populations are not well understood, and studies attempting to quantify their impact have had mixed results (Kelly et al. 2003; Olson et al. 2005). Regardless of the potential threats posed by Barred Owls, there is still a need for structurally complex forests to sustain Spotted Owls, and there is no indication that the current reserve system is less functional because of this threat (Courtney et al. 2004). Therefore, our model focused on the habitat features that are necessary to sustain Spotted Owls in spite of potential threats.

Overall, our findings suggest that the NWFP has adequately met most of its ecological goals, but as conditions change over time, managers need to be able to make reasoned decisions even in the face of incomplete information. Our model results provide a landscape-level overview of areas of HCV that could guide the decisions of land managers as they try to meet objectives of the NWFP over time (Fig. 1). On the basis of our interpretation of possible shortcomings of the existing

NWFP, such as connectivity, we chose eight examples of areas that may be of interest to land managers and discuss the significance of each to illustrate how a decision-support model could be used to inform land-management decisions.

Areas 2, 5, 6, 7, and 8 in Fig. 1 contain both high-value aquatic habitat and high-value stream and landscape connectivity located mostly on public land. Thus, these areas warrant closer inspection from those wishing to manage for several values simultaneously. Landscape connectivity may be of particular importance because it has been identified as necessary for Spotted Owl dispersal from reserve to reserve and across the matrix (Thomas et al. 1990). Although dispersal habitat in general appears to be adequate within the NWFP, there remain some localized areas, such as the Oregon Coast Range, where this habitat has been identified as lacking (USDI 1992). Our model indicated areas of moderate to high conservation value that could be investigated further for management actions that would promote landscape connectivity. In particular, areas 2 and 6 provide the only suitable older forest habitat for Spotted Owls and Marbled Murrelets on publicly managed lands for large stretches, especially in the Coos Bay District (area 6), where large gaps between federal lands are filled with private industrial forests. In addition, areas 5 and 7 include habitat that could provide enhanced connectivity between LSOG in the Coast and Cascades ranges.

The BLM lands in western Oregon play a pivotal role in connectivity between public lands in the Coast Range and the Cascades, as well as in southwest Oregon linking the Klamath, Coast, and Cascade Provinces (Thomas et al. 1990); however, the majority of public lands located in areas 2, 5, and 6 are managed with minimal levels of protection. Our model suggests that BLM should consider the importance of these areas for landscape connectivity in future revisions of the forest plan.

A notable benefit of the EMDS modeling process is that the entire landscape is evaluated regardless of land ownership. Therefore, in addition to the areas of public HCV mentioned above, our model indicated areas of HCV that are on private land and may be of interest to land managers. For example, areas 1, 3, and 4 showed strong support for terrestrial species value (Marbled Murrelets area 3 and owl's areas 1 and 4) that may become important if population declines persist. Although private lands pose greater challenges when managing for ecological values across a landscape, it may be possible through the use of conservation easements or habitat conservation plans (HCP).

We identified sections that contained habitat of moderate to high conservation value (Fig. 1), but managers may be interested in identifying areas that meet specific criteria of interest for finer-scale planning and decision making. For example, it may be important to identify sections of exceptional HCV to narrow down areas of interest for future planning. Figure 3 shows only sections with a conservation value score of >0.7; thus, this map indicates areas of exceptional HCV that are currently minimally or not protected in reserves.

In particular, area A (Fig. 3) encompasses a large patch of HCV sections that are minimally protected in the Zane Grey Roadless Area along the Rogue River in southwestern Oregon (BLM Medford District), the largest forested BLM roadless area in the contiguous United States. The area is adjacent to a strictly protected wilderness area (Wild Rogue), provides high-quality Spotted Owl habitat, and has high forest value.

Areas B and C (Fig. 3) also stand out as priorities within our model. Area B is managed by the BLM and provides owl habitat, intact LSOG ecosystems, and connectivity of LSOG habitat across the landscape, all important objectives of the NWFP. Although currently managed as an adaptive management area in which alternative management strategies can be tested before being adopted in larger areas, the BLM has considered plans to use this area for intensive timber harvest (BLM 2008). Area C is located in the Willamette National Forest and could provide important habitat for owls and other LSOG-associated species while increasing habitat connectivity in the region.

Our model is not limited to the evaluation of HCV areas across the landscape. In particular, managers should consider the contributions of topics at each level (e.g., primary, secondary) when interpreting a final evaluation. For example, sections identified as containing HCV habitat may vary substantially at the level of primary topic (e.g., terrestrial or aquatic value) or lower levels. Thus, a manager interested in identifying areas of high value for fishes would be more interested in viewing the results of that specific topic, rather than looking at the final evaluation for HCV areas in general. This is a particular strength of the EMDS model in that the results are transparent at all levels of the underlying logic model and interpretation of the final results is straightforward and understandable to users.

The examples presented above should not be construed as a detailed management plan for the NWFP area; rather, they provide a snapshot of current ecological conditions across the landscape and a starting point for making decisions regarding finer-scale planning. When doing actual planning, managers may want to vary the reference points or use different data inputs to test various management scenarios that are based on the stated goals and objectives of the project.

Model Validation

Because all models are simplifications of reality, our model requires verification and validation. To verify our model, we must show that it does in fact indicate areas of HCV on the landscape, so we compared areas we mapped

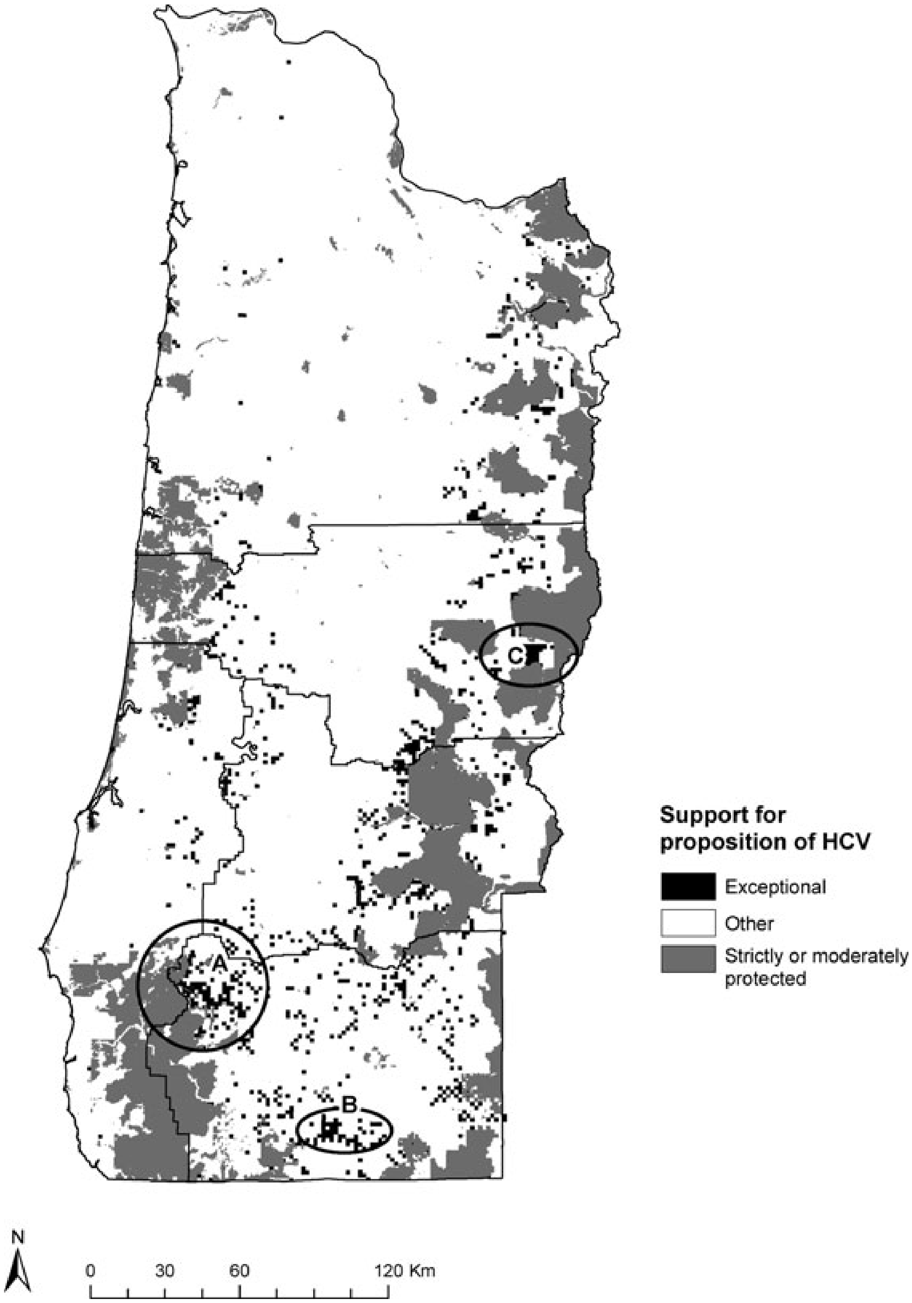

Figure 3. Model results showing areas of exceptionally high conservation value (HCV) (support for proposition of HCV > 0.7) in the study area. Circles represent priority areas for management consideration.

as HCV areas with those that have been independently chosen to support the ecological values of the NWFP. The LSRs were set-aside specifically to protect areas with concentrations of high-quality LSOG forest and to meet the habitat requirements of Spotted Owls and Marbled Murrelets (Thomas et al. 2006) and thus should score as HCV areas in our model. This is largely the case; 87% of LSRs were of moderate (49%) or strong (38%) conservation value. In addition, the fact that 93% of sections identified as having no HCV habitat were located on private land (which is generally managed for intensive human uses) provides some verification for our model.

Models are validated when predicted and actual outcomes are objectively compared. Therefore, models must be tested on the ground before they can be validated, which was beyond the scope of this project. We recommend that land managers who use decision-support models should make validation of their model an integral part of their management plans. Nevertheless, we identified some shortcomings of our model that should be considered when interpreting the results.

Evaluation outcomes were directly affected by quality of the data sets and premises of the underlying logic model. Our data sets were at a relatively fine scale

(1:100,000 or finer) and were obtained from federal agencies that use them for their own planning. Some model inputs, however, were better defined spatially than others. For example, our model relied heavily on surrogate data for aquatic values and would benefit from the addition of high-quality aquatic data sets that indicate specific attributes of stream quality, such as sedimentation and temperature, as soon as these become available.

Conclusions

Our results show how the EMDS decision-support model could help land managers better achieve their ecological goals. Such models have been used to evaluate a variety of land-management issues, such as the danger of severe wildland fire in subwatersheds of the Rocky Mountains (Hessburg et al. 2007), watershed conditions for the USFS (Reynolds et al. 2000), and evaluation and prioritization of land units for conservation (Bourgeron et al. 2000).

The advantage of models like EMDS is that they allow complex or abstract issues to be broken down into manageable parts that are easier to analyze. Decision-support models require users to provide explicit representations of the underlying logic of the problem, which allows them to more effectively communicate their decisions to others. Rather than being a "black box," EMDS allows decision makers to clearly show the contributions of intermediate model steps to the final results and justify the underlying data and logic to the general public. This is especially important when dealing with controversial issues such as the NWFP. Thus, decision makers should consider the use of decision-support models when developing complex land-management plans that deal with multiple objectives over large landscapes of varying ownership.

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Literature Cited

BLM (Bureau of Land Management). 2008. Final environmental impact statement for the revision of the resource management plans of the western Oregon Bureau of Land Management districts. Volumes I-IV. BLM, Washington, D.C.

Bourgeron, P. S., H. C. Humphries, and K. M. Reynolds. 2000. Conducting large-scale conservation evaluation and conservation area selection using a knowledge-based system. 4th International Conference on Integrating GIS and Environmental Modeling: Problems, Prospects, and Research Needs. Banff, Alberta, Canada, September 2–8.

Courtney, S. P. et al., editors. 2004. Scientific evaluation of the status of the Northern Spotted Owl. Sustainable Ecosystems Institute, Portland, Oregon.

DellaSala, D. A., S. B. Reid, T. J. Frest, J. R. Strittholt, and D. M. Olson. 1999. A global perspective on the biodiversity of the Klamath-Siskiyou ecoregion. Natural Areas Journal **19:**300–319.

DellaSala, D. A., N. L. Staus, J. R. Strittholt, A. Hackman, and A. Iacobelli. 2001. An updated protected areas database for the United States and Canada. Natural Areas Journal **21:**124–135.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. Oregon State University Press, Corvallis, Oregon.

Gap Analysis Program. 2000. A handbook for conducting gap analysis. U.S. Geological Survey Gap Analysis Program, Moscow, Idaho. Available from http://www.gap.uidaho.edu/handbook/CompleteHandbook.pdf (accessed June 2009).

Hessburg, P. F., K. M. Reynolds, R. E. Keane, K. M. James, and R. B. Salter. 2007. Evaluating wildland fire danger and prioritizing vegetation and fuels treatments. Forest Ecology and Management **247:** 1–17.

Jennings, S., et al. 2003. The high conservation value forest toolkit. High Conservation Value Resource Network, Proforest, Oxford, United Kingdom. Available from http://www.hcvnetwork.org/resources/global-hcv-toolkits (accessed June 2009).

Kelly, E. G., E. D. Forsman, and R. G. Anthony. 2003. Are Barred Owls displacing Spotted Owls? The Condor **105:**45–53.

Lint, J. 2005. Northwest Forest Plan—the first 10 years (1994–2003): status and trends of Northern Spotted Owl populations and habitat. General technical report PNW-GTR-648. U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Marcot, B. G., and R. Molina. 2006. Conservation of other species associated with older forest conditions. Pages 145–179 in R. W. Haynes, B. T. Borman, D. C. Lee, and J. R. Martin, technical editors. The Northwest Forest Plan—the first 10 years (1994–2003): a synthesis of monitoring and research results. General technical report PNW-GTR-651. U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, Oregon.

McGarigal, K., S. A. Cushman, M. C. Neel, and E. Ene. 2002. FRAGSTATS 3.0: spatial pattern analysis program for categorical maps. University of Massachusetts, Amherst, Massachusetts.

McShane, C., et al. 2004. Evaluation report for the 5-year status review for the Marbled Murrelet in Washington, Oregon, and California. Report. U.S. Fish and Wildlife Service, Region 1, Portland, Oregon.

Moeur, M., T. A. Spies, M. A. Hemstrom, J. Alegria, J. Browning, J. H. Cissel, W. B. Cohen, T. E. Demeo, S. Healy, and R. Warbington. 2005. The Northwest Forest Plan—the first 10 years (1994–2003): status and trends of late-successional and old-growth forests. General technical report PNW-GTR-646. U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Noon, B. R., and J. A. Blakesley. 2006. Conservation of the Northern Spotted Owl under the Northwest Forest Plan. Conservation Biology **20:**288–296.

Noon, B. R., and K. S. McKelvey. 1996. Management of the Spotted Owl: a case history in conservation biology. Annual Review Ecology and Systematics **27:**135–162.

Olson, G. S., R. G. Anthony, E. D. Forsman, S. H. Ackers, P. J. Loschl, J. A. Reid, K. M. Dugger, E. M. Glenn, and W. J. Ripple. 2005. Modeling of site occupancy dynamics for Northern Spotted Owls, with emphasis on the effects of barred owls. Journal of Wildlife Management **69:**918–932.

Raphael, M. G. 2006. Conservation of the Marbled Murrelet under the Northwest Forest Plan. Conservation Biology **20:**297–305.

Reeves, G. H., J. E. Williams, K. M. Burnett, and K. Gallo. 2006. The Aquatic Conservation Strategy of the Northwest Forest Plan. Conservation Biology **20:**319–329.

Reynolds, K. M., 1999. NetWeaver for EMDS version 2.0 user guide: a knowledge base development system. General technical report

PNW-GTR 471. U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, Oregon.
Reynolds, K. M., M. Jensen, J. Andreasen, and I. Goodman. 2000. Knowledge-based assessment of watershed condition. Computers and Electronics in Agriculture **27:**315–333.
Ricketts, T., et al. 1999. Terrestrial ecoregions of North America: a conservation assessment. Island Press, Washington, D.C.
Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Meslow, B. R. Noon, and J. Verner. 1990. A conservation strategy for the Northern Spotted Owl: Interagency Scientific Committee to address the conservation of the Northern Spotted Owl. U.S. Department of Agriculture, Pacific Northwest Research Station, Portland, Oregon.
Thomas, J. W., J. F. Franklin, J. Gordon, and K. N. Johnson. 2006. The Northwest Forest Plan: origins, components, implementation experience, and suggestions for change. Conservation Biology **20:**277–287.
USDA (U.S. Department of Agriculture). 1994. Record of decision for the amendments to Forest Service and BLM planning documents within the range of the Northern Spotted Owl and standards and guidelines for management of habitat for late-successional and old-growth forest within the range of the Northern Spotted Owl. USDA Forest Service, Portland, Oregon, and BLM, Moscow, Idaho.
U.S. Department of the Interior (USDI). 1992. Final draft recovery plan for the Northern Spotted Owl. Report. USDI, Washington, D.C.