# ISSUES AND ALTERNATIVES ASSOCIATED WITH PRIVATE FOREST WILDLIFE AND RIPARIAN HABITAT MANAGEMENT

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## ABSTRACT

Efforts to provide habitat for species in decline invariably fall back on managing stands to emulate older forest conditions as the forest structure in greatest decline. To more quickly achieve old forest structural conditions that were thought important to the survival of the northern spotted owl (*Strix occidentalis*), biodiversity thinning pathways were designed to reinitiate understory and more complex structures including consideration for retaining downed logs, snags and multiple canopy layers. Stream buffer rules have since evolved to target natural old forest conditions as the desired future condition (DFC) along streams. The economics of no-management and even longer rotations to achieve old forest structures generally falls below acceptable rates of return providing motivation for land conversion. Alternative management approaches that allow thinning treatments and narrow buffers cost landowners much less, reduce the motivation for land-conversions, and have been shown to accelerate development of desired old forest conditions along streams. Thinning in upland stands improves young forest habitat at minimal cost while placing stands on a trajectory that can ultimately produce old forest structure albeit at an unacceptable cost for private owners. Incentives coupled with thinning harvests can be used to offset landowner losses and may help reduce the motivation for land conversion while contributing to achievement of habitat objectives.

KEYWORDS: Riparian buffers, forest regulations, sustainable forestry, biodiversity pathways, old forest habitat, private forests.

## INTRODUCTION

Two decades ago, declines in old forest habitats with consequent impacts on certain species such as the northern spotted owl prompted interest in forest management strategies that integrate protection of habitat and other ecological values with acceptable economic returns. In 1993, the Washington Forest Landscape Management Project brought together an interdisciplinary team of scientists to investigate the potential for intentionally managing stands to accelerate development of old forest conditions as a method that might improve wildlife habitat and avoid future endangered species listings (Carey et al. 1996, Carey et al. 1999, Lippke et al. 1996). Old forest habitat has declined as a consequence of commercial management, forest conversions, and disturbance events that result in continued risk of habitat loss and species listings in absence of direct attempts to provide more of these old forest conditions. A range of prescriptive treatments called biodiversity pathways was developed to accelerate old forest functionality while providing economic revenues. The treatments were characterized by repeated thinnings and longer rotations than typical commercial management, with attention to retaining downed logs, snags, and multi-layered canopies. Evaluations of the biodiversity pathways indicate that they could be used to develop late seral characteristics in young, dense, managed stands more rapidly and at less cost than by setting the stands aside as no-harvest reserves, which would require a long time for natural processes to result in the desired structural diversity associated with older forests.

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More recently, in response to declining salmon runs, attention has shifted towards mitigating the environmental impacts associated with commercial forest management adjacent to streams in the Pacific Northwest. Similar to habitat objectives for the protection of upland species, the goal of riparian harvest regulations in Washington and Oregon is to allow the development of riparian forest structure similar to more complex older forests, also referred to as the desired future conditions (DFC). An especially important component of the DFC is the development of large conifers as a source of shade and long-term large woody debris (LWD) recruitment to streams. In the absence of active management it will likely take an undesirably long time for riparian areas in young, dense stands to achieve the DFC (Carey et al. 1999, Chan et al. 2004). This is especially true in Washington, which requires wider buffers with significant portions where no harvesting is allowed.

The riparian harvest regulations in both Oregon and Washington permit landowners to deviate from the regulatory prescription and pursue alternative management plans for stands that are unlikely to achieve DFC without active management. The Washington regulations further suggest that management templates be developed for riparian stands that are overly dense, which are expected to be common situations given historical management practices. Templates would provide specific guidelines to streamline the process for developing and approving alternate plans.

The principle biodiversity pathways that were developed earlier to restore old forest conditions in upland areas provide useful guidance for managing riparian forests for old forest structure as well. This management approach was noted early-on as an alternative to reduce the cost of no-harvest stream buffers in the development of the Washington State Department of Natural Resources (WDNR) Habitat Conservation Plan (Bare et al. 1997), and it has since been evaluated more thoroughly in an examination of sustainable harvest practices on state forests in western Washington (WDNR 2004). In an examination of management alternatives for small private forestlands, Zobrist et al. (2004, 2005) found that landowners, through a series of thinning harvests modeled as biodiversity pathways, could achieve the long-term desired condition of old forest structure in riparian zones while protecting short-term functions and maintaining an acceptable economic return.

A defining characteristic of the biodiversity pathways is that treatments must start early in young, dense stands so that the height-to-diameter ratio for the retained trees is low enough to resist wind-throw, there is enough live crown for a vigorous treatment response, and the maximum structure benefit is achieved over time. Since dense, closed-canopy stands offer the least habitat diversity, early thinnings tend to support understory development with increased habitat at a young age while also putting stands on a trajectory to develop more older forest functionality in the long run. Thus these pathways achieve multiple habitat objectives over time. Concurrently, thinnings provide early revenue opportunities to partially offset the economic costs of longer rotations. This paper will develop the use of these methods for managing riparian and upland forests for better habitat while noting some of the many ecological and economic complexities that need to be understood to promote sustainable forest policies and avoid unintended consequences.

## ASSESSING HABITAT QUALITY

A challenge with biodiversity pathways is how to identify the best management alternatives. Since the goal of the treatment path is to develop a desired stand structure, a statistical assessment procedure was developed to determine how well a given pathway produces stand structure similar to that of older forest structures (Gehringer 2006). Treatment alternatives can be simulated to see how long it takes for a stand to develop old forest conditions and how long that the stand retains those conditions. Greater tree height and diameter, and lower stand density provide most of the discriminating characteristics that structurally describe an older forest in the Pacific Northwest.

The assessment procedure, in combination with an economic assessment of treatment alternatives, can provide a coarse filter for identifying the most successful management pathways. Management alternatives that produce old forest structure are likely to be more sustainable if economic returns are sufficient to sustain the land in forestry with a lower risk of conversion to other uses. Supplemental screening of alternatives can also be applied using additional metrics of interest, such as the potential for LWD recruitment to streams. The variability of LWD recruitment potential is so high, even in old forests, that it does not help in the discrimination of old forest conditions. However, alternatives that produce the DFC and also have high LWD recruitment potential are considered more desirable for stream protection on the Westside.

## DEVELOPING TEMPLATES

To identify the best treatment alternatives, a range of biodiversity pathways are defined and evaluated for the percent of time they result in statistically similar structure to old forests, provide sustainable economic returns, and provide other specific attributes of interest such as LWD for stream habitat or snags that provide habitat for woodpeckers and other species. Best performing alternatives can be developed as templates, which would provide pre-established management guidelines for an appropriate range of site parameters. Templates would minimize the time and expense for management planning for landowners, providing both the timing information needed for treatments and a robust ecological and economic justification for the management approach. We will present example management alternatives and a corresponding simplified template designed for implementation of the best management alternatives at a reasonable cost.

## EXAMPLE RIPARIAN MANAGEMENT TARGETS

To develop a management template for producing old forest conditions in riparian areas, quantitative, objective evaluation criteria are needed. To develop a first order ecological criterion to assess pathways relative to the DFC, a reference dataset was established using subplots from the Pacific Resource Inventory, Monitoring, and Evaluation (PRIME) database, which is part of the USDA Forest Service's Forest Inventory and Analysis (FIA) program. To select conditions representative of the DFC (mature, unmanaged, riparian stands), subplots were selected that were at least 80 years old, were within 215 ft of a stream and did not have a history of management.

The structural attributes of this reference dataset were used to create a quantitative management target representing the DFC. Potential management plans could then be assessed to determine whether they achieve the target, producing a structure that was statistically similar to the DFC (Gehringer 2006). Three attributes provided the best discrimination in describing the structure of the reference dataset: stand density in trees per acre (TPA), quadratic mean diameter (QMD), and average height computed using only trees having a diameter at breast height (DBH) greater than 12 in. The distribution of values for these attributes, when considered simultaneously, established a three-dimensional target region. The target region was then refined by identifying a 90 percent acceptance region around the mode (the most likely value of the data distribution) to reduce the influence of the most extreme or outlying data points (fig. 1). An observed stand condition in which the density, QMD, and average height fall simultaneously within the 90 percent target acceptance region would be statistically similar to the DFC reference dataset.

The percentage of time over a 140-year assessment period (assessed at five-year intervals) that the stand structure for a projected management option fell within the target was established as the specific ecological performance criterion for potential management templates. This criterion allowed the selection of template options that achieved the DFC quickly, maintained it until a regeneration harvest, and then quickly re-attained it in the subsequent rotation.

In addition to an ecological criterion, an economic criterion is needed. Soil expectation value (SEV), or bare land value, is the net present value of a complete forest rotation repeated in perpetuity given a target rate of return (Klemperer 1996). This is perhaps the most important single economic criterion, as it measures the economic performance of the initial investment and whether it provides an acceptable rate of return to sustain the land under forest management. Soil expectation value is also relevant for landowners starting with mid-rotation stands, as at some point they will reach the end of a rotation and be faced with the decision of whether or not to continue the template for additional rotations. Soil expectation value was computed using a five percent real cost of money.

## ASSESSING TEMPLATE ALTERNATIVES

Using the biodiversity pathway model, we defined a range of alternatives that incorporated repeated heavy thinnings over long rotations to enhance riparian forest structure while providing acceptable economic returns. These alternatives were designed for Douglas-fir stands with mid-high site quality and each alternative was a variation of a base 100-year rotation. This base rotation included three commercial thinnings, the first of which was an early commercial thinning from below to 180 TPA at age 20. Early commercial thinnings are being utilized in lieu of pre-commercial thinnings, given new markets for small diameter wood (Talbert and Marshall 2005). Subsequent thinnings from below to 60 TPA at age 50 and to 25 TPA at age 70 were performed. A clearcut harvest was done at age 100, followed by replanting Douglas-fir to a typical density of 435 TPA (Talbert and Marshall 2005). In order to keep the costs of riparian treatments low, the timing of these entries was chosen to correspond with upland operations, which were assumed to be done on a 50-year rotation with a commercial thinning at age 20 (table 1).

A total of 18 potential template alternatives were generated from which to select those with the best ecological and economic performance as the basis for template development. Each alternative included a 25-ft no clearcut zone to provide for continuous shade and bank stability. One of

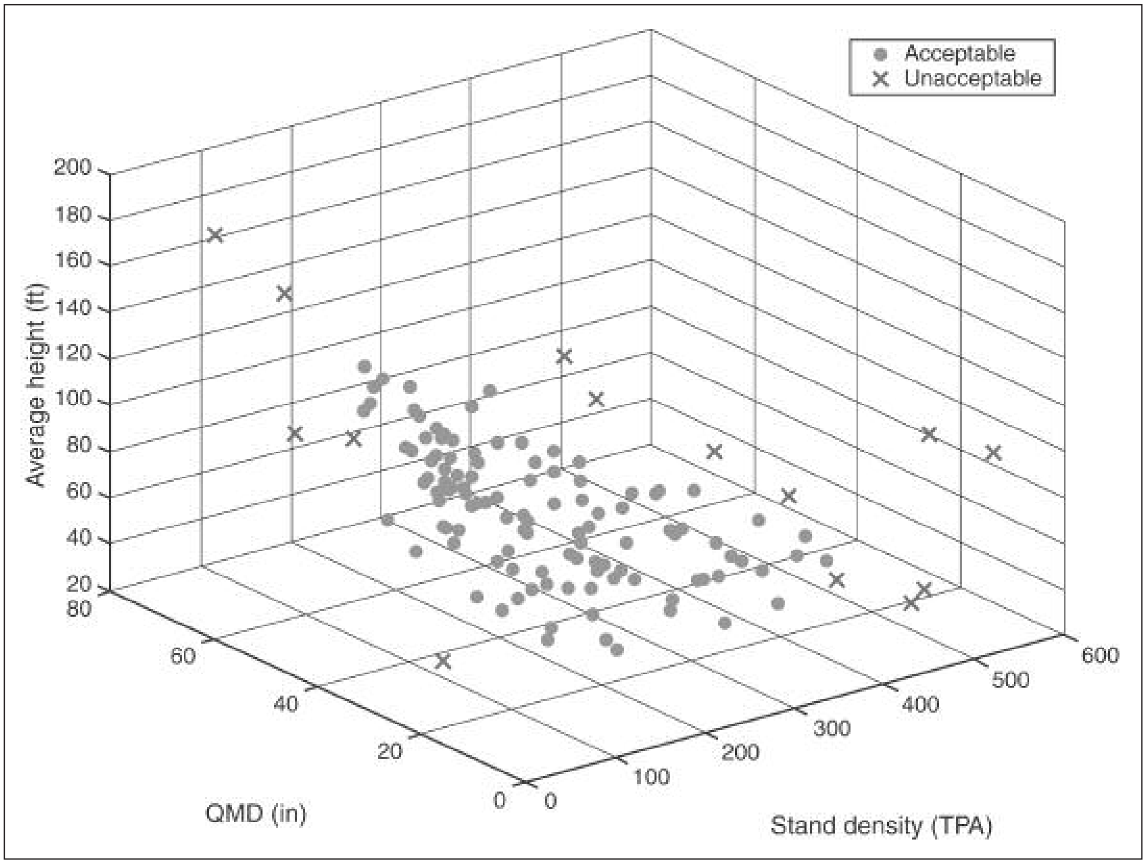

Figure 1—The 90 percent acceptance region of the three-dimensional structure target. The grey dots represent the central 90 percent of the DFC dataset, while the black Xs represent the most extreme ten percent of the data points that are rejected as the outlying values. A stand whose observed attributes fell within the 90 percent acceptance cluster would be statistically similar to the DFC dataset.

three prescriptions was applied in this zone: no action, no entry after thinning to 60 TPA (60-hold), or no entry after thinning to 25 TPA (25-hold). Beyond this bank stability zone, either 25-hold or the full 100-year rotation was applied. There were three total buffer widths used: 50-, 80-, and 113-ft. These widths corresponded to divisions between buffer zones for site class II under the Washington regulations. The total width of the riparian zone was 170 ft, and was based on the site potential tree height for site class II. The portion of the riparian zone beyond the buffer was assumed to be managed with the upland areas (50-year rotation). Specific prescriptions for the 18 alternatives are listed in table 2.

The 18 riparian management alternatives were simulated over time using the Landscape Management System (LMS). Landscape Management System is a program that integrates growth, treatment, and visualization models under a single, user-friendly interface (McCarter et al. 1998). Landscape Management System includes a number of regional variants of publicly available single-tree growth models. The Stand Management Cooperative (SMC) variant of the ORGANON growth model was used to simulate the template options (Hann et al. 1997). Simulations were begun using an initial inventory from a 20-year-old Douglas-fir plantation in southwestern Washington that is representative of a dense plantation approaching its first commercial thinning (fig. 2). The plantation had 472 TPA and a 50-year site index of 120 ft. The simulation length was 140 years for all prescriptions. For prescriptions that included a regen-eration harvest (the 100-year rotation and the 50-year upland rotation), replanting was done to 435 TPA and the rotation repeated as necessary.

Using LMS projections of tree lists, stand structures relative to the target conditions were assessed over time. Each management segment of the riparian area (the bank stability zone, remaining buffer, and the riparian area out-

**Table 1—Timeline of riparian entries and corresponding upland operations for the 100-year Douglas-fir rotation defined for potential riparian template options based on the biodiversity pathway approach**

| Year | Riparian entry | Corresponding upland operation |
|---|---|---|
| 20 | Thin to 180 TPA | Thin to 180 TPA |
| 50 | Thin to 60 TPA | Clearcut and replant |
| 70 | Thin to 25 TPA | Thin to 180 TPA |
| 100 | Clearcut and replant | Clearcut and replant |

**Table 2—18 potential template alternatives. Each alternative had a 25-ft no clearcut bank stability zone that was thinned to 60 TPA, 25 TPA, or left unthinned. The remaining portion of the buffer varied in width and was either thinned to 25 TPA or managed on a 100-year clearcut rotation**

| Alternative | Bank stability zone prescription | Remaining buffer prescription | Total buffer width (ft) |
|---|---|---|---|
| 1 | No action | 25-hold | 113 |
| 2 | No action | 100-year | 113 |
| 3 | No action | 25-hold | 80 |
| 4 | No action | 100-year | 80 |
| 5 | No action | 25-hold | 50 |
| 6 | No action | 100-year | 50 |
| 7 | 60-hold | 25-hold | 113 |
| 8 | 60-hold | 100-year | 113 |
| 9 | 60-hold | 25-hold | 80 |
| 10 | 60-hold | 100-year | 80 |
| 11 | 60-hold | 25-hold | 50 |
| 12 | 60-hold | 100-year | 50 |
| 13 | 25-hold | 25-hold | 113 |
| 14 | 25-hold | 100-year | 113 |
| 15 | 25-hold | 25-hold | 80 |
| 16 | 25-hold | 100-year | 80 |
| 17 | 25-hold | 25-hold | 50 |
| 18 | 25-hold | 100-year | 50 |

side the buffer) was assessed independently, and a weighted average was used to obtain an assessment score. Recognizing that the portions of the riparian area closest to the stream are more critical for key riparian functions such as LWD recruitment, greater weight was given for closer proximity to the stream. To calculate the weights, potential LWD recruitment volume was simulated for the DFC dataset using a model that estimates the expected values for potentially available LWD (Gehringer 2005). The average percent of the cumulative potentially available LWD volume derived using the DFC dataset was then plotted by distance from the stream out to the site potential tree height of 170 ft where 100 percent of the potential LWD volume was included (Meleason et al. 2003) (fig. 3). The weights used for a management segment of a given width and distance from the stream were computed as the proportion of the cumulative potential LWD volume recruitment for the corresponding segment of the cumulative curve.

To assess economic performance, SEV was computed for each alternative using local log prices and treatment

Figure 2—Photo and SVS visualization of the representative inventory used to simulate potential template alternatives. The inventory is from a Douglas-fir plantation in southwest Washington. Photograph taken by Kevin Zobrist.

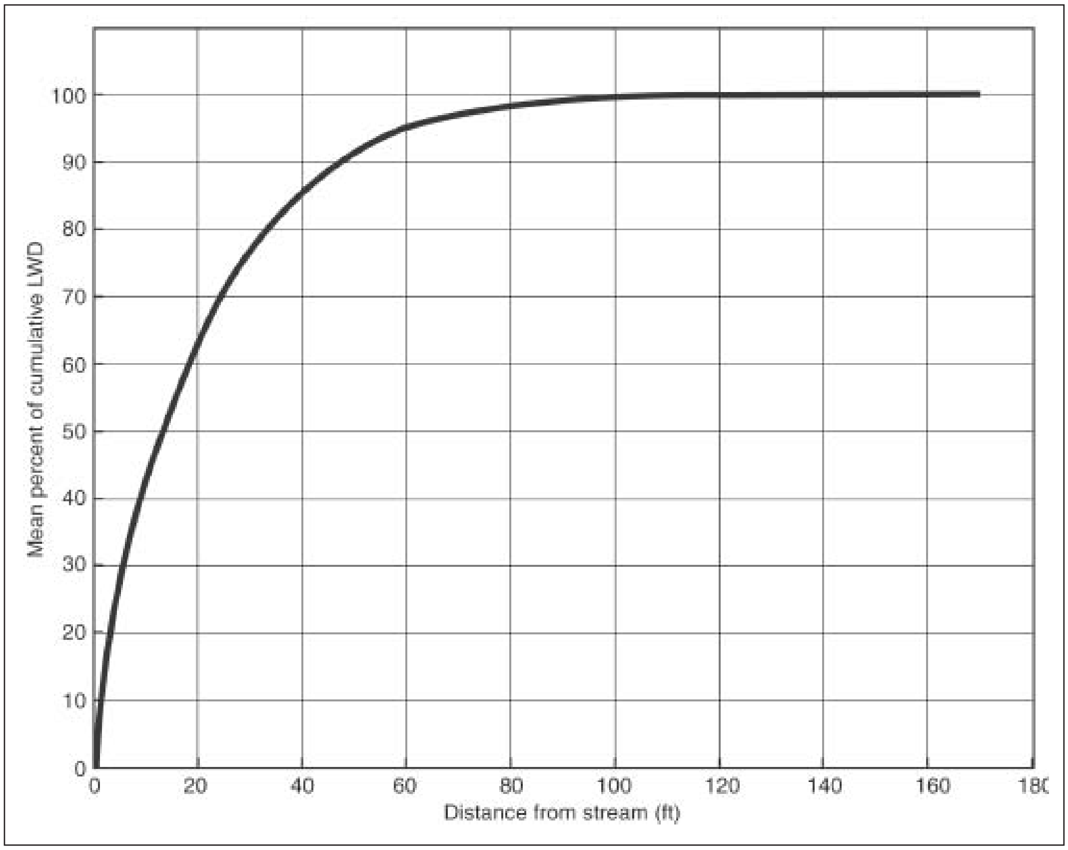

Figure 3—The average percent of the cumulative potential LWD volume recruitment by distance from the stream, based on simulations of potentially available LWD using the DFC dataset.

**Table 3—Percent time in target over a 140-year assessment period, along with soil expectation values (SEV) per riparian acre for the no harvest alternative, default regulatory prescription, and 18 potential template alternatives**

| Alternative | Time in target | SEV/acre |
|---|---|---|
| | *Percent* | *Dollars* |
| Washington regulations | 32.1 | (215) |
| No Harvest | 31.0 | (800) |
| 1 | 40.1 | (322) |
| 2 | 46.1 | 106 |
| 3 | 40.1 | (45) |
| 4 | 45.8 | 222 |
| 5 | 39.9 | 207 |
| 6 | 44.1 | 329 |
| 7 | 64.5 | (322) |
| 8 | 70.5 | 106 |
| 9 | 64.5 | (45) |
| 10 | 70.2 | 222 |
| 11 | 64.2 | 207 |
| 12 | 68.5 | 329 |
| 13 | 62.1 | (322) |
| 14 | 68.1 | 106 |
| 15 | 62.0 | (45) |
| 16 | 67.7 | 222 |
| 17 | 61.8 | 207 |
| 18 | 66.1 | 329 |

Note: Parentheses indicate negative values.

costs[4]. Soil expectation value was calculated from the cumulative economic contribution of each management segment of the riparian area out to the 170-ft site potential tree height as the extremity of the riparian area. The overall economic performance of a stand depends on the combined performance of the riparian and upland areas. However, identifying management alternatives that achieve viable economic returns for the riparian area ensures that riparian areas do not cause a loss of economic viability, even when they comprise a high proportion of a stand.

## IDENTIFYING PREFERRED TEMPLATE ALTERNATIVES

The percent time in target over a 140-year assessment period, along with SEV per riparian acre, is summarized in table 3 for the 18 potential template alternatives. The default prescription under the Washington regulations[5] and a no riparian harvest alternative are included as reference points. For riparian templates to be implemented, the performance of the default regulatory option could be considered as a threshold for acceptance since protection should be at least as good as the default regulatory prescription.[6]

The no harvest alternative performed the worst relative to both the DFC and economic criteria. Maintaining a dense stand with no thinning delayed the achievement of the DFC, resulting in a low time in target score. The lack of harvest revenue resulted in a net economic cost per acre, as the only cash flows were the annual overhead costs, which are assumed to apply regardless of whether a harvest occurs. This resulted in a negative SEV (-$800). The regulatory prescription only had a marginally higher time in target score than the no harvest alternative, as the regulatory prescription called for no harvest within 80 ft of the stream– this is the portion of the riparian zone which provides the majority of the potential LWD volume and has a score weight of almost 100 percent (fig. 3). The SEV for the regulatory prescription was negative, as there was not enough harvest revenue to achieve the five percent target rate of return.

All 18 of the potential template alternatives performed better than the regulatory prescription, as the biodiversity thinnings accelerated the development of the DFC, achieving greater time in target scores. Alternatives 1-6 had the lowest time in target scores of the 18 alternatives, as these alternatives did not include any thinning in the first 25 ft, which carries a scoring weight of 0.71 (fig. 3). Economic performance was driven by the total buffer width and whether or not a regeneration harvest was allowed in the area outside the bank stability zone. For the alternatives that did not have a regeneration harvest outside the bank

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[4] Average Puget Sound region delivered log prices for 2000 were used, as reported by Log Lines. Logging and hauling costs were based on Lippke et al. (1996) and varied by the average DBH of the harvested trees and whether the harvest was a clear-cut or thinning operation. The early commercial thinning at age 20 was assumed to break even, with no net cost or revenue. Planting costs were assumed to be $0.55/seedling ($239/acre for 435 TPA). Since this template was developed with smaller, non-industrial landowners in mind, relatively high annual overhead costs of $40/acre were used. For larger or industrial landowners, $17/acre were considered appropriate. All financial calculations were done before taxes.

[5] Washington regulations allow several management options. It is assumed that the default option for a clear-cut harvest is “Option 2,” which requires a minimum 80-foot no harvest area, followed by retention of 20 conifers per acre greater than 12 inches in DBH out to edge of the riparian zone at 170 feet.

[6] The regulations do not specify a performance standard for riparian protection, but given that the stated intent of the regulations is to develop the DFC, time in target was assumed to be a reasonable criterion.

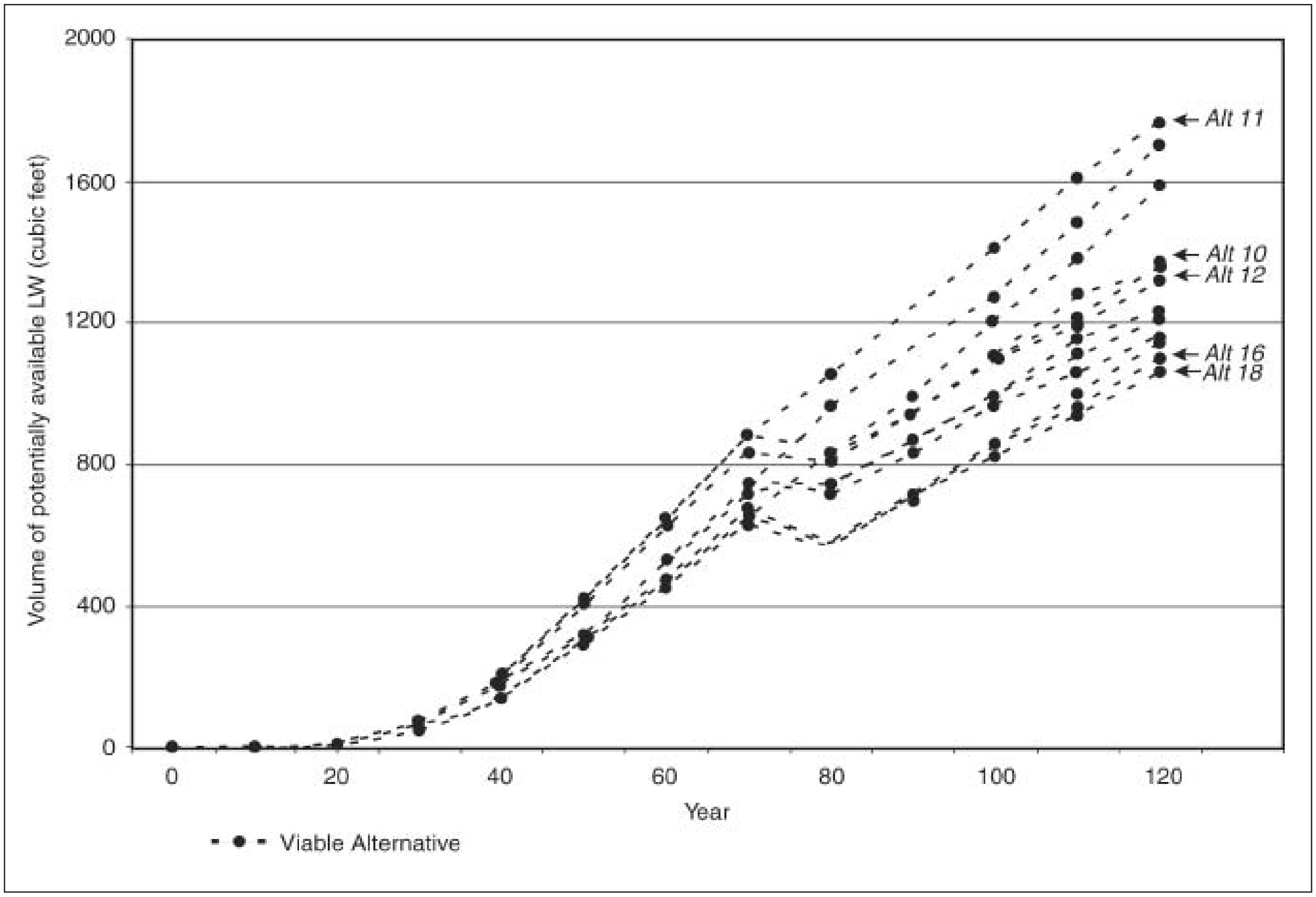

Figure 4—Potentially available LWD volume over time for the 12 viable template alternatives. Alternative 10 had the largest final volume of the four alternatives that performed best in the coarse filter assessment, and alternative 11 had the largest final volume of all viable alternatives.

stability zone (25-hold instead of 100-year), no further harvest was done after the third thinning to 25 TPA, which was assumed to preclude subsequent rotations. As with the no harvest prescription, this resulted in a negative SEV (-$800) for those segments, as the only perpetual cash flows beyond the current rotation were the annual overhead costs.

A total of 12 out of the 18 potential alternatives could be considered as viable template options, having achieved both increased time in target values and the five percent target rate of return (SEV > $0). Alternatives 10, 12, 16, and 18 performed particularly well relative to both criteria. This allowed adding an additional potentially available LWD as a fine filter screening criterion to refine the set of viable options down to one or two preferred alternatives. LWD provides important in-stream functions, and long-term sources of LWD are typically lacking in areas of intensive management (Bilby and Bisson 1998). The potential LWD volume was simulated for the 12 viable template alternatives using a potentially available LWD model (Gehringer 2005). The potentially available LWD volume for each alternative is plotted in figure 4.

Of the four alternatives that performed best in the coarse filter assessment, alternative 10 provided the largest level of potentially available LWD volume at the end of the 120-year simulation, with a value of 1,369 ft$^3$. Alternative 11 also warranted consideration, as it provided the largest level of potentially available LWD at the end of the 120-year simulation of all of the viable alternatives, with a value of 1,761 ft$^3$. While this alternative did not perform as well as others in the initial template assessment, it still met the minimum criteria, and its higher LWD volume made it a desirable second option.

Two preferred options emerged from the fine filter assessment: alternatives 10 and 11. Both alternatives called for the 60-hold prescription in the 25-ft bank stability zone. Alternative 10 had a wider total buffer width of 80 ft, but

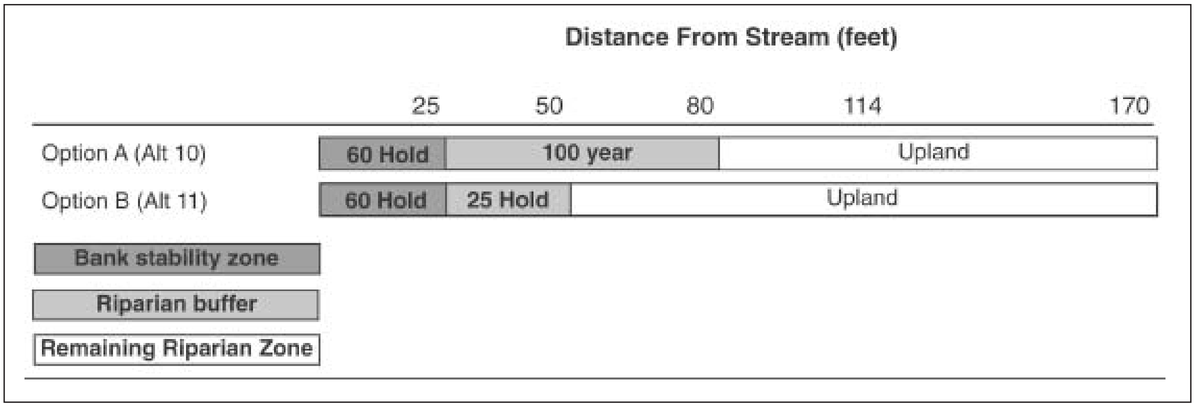

Figure 5—Using the fine filter criterion, two preferred alternatives emerged: alternative 10 and alternative 11. These became Option A and Option B respectively for the template. Option A had a wider buffer but allowed a regeneration harvest outside the bank stability zone, whereas Option B had a narrower buffer but allowed no further entries after the third thinning.

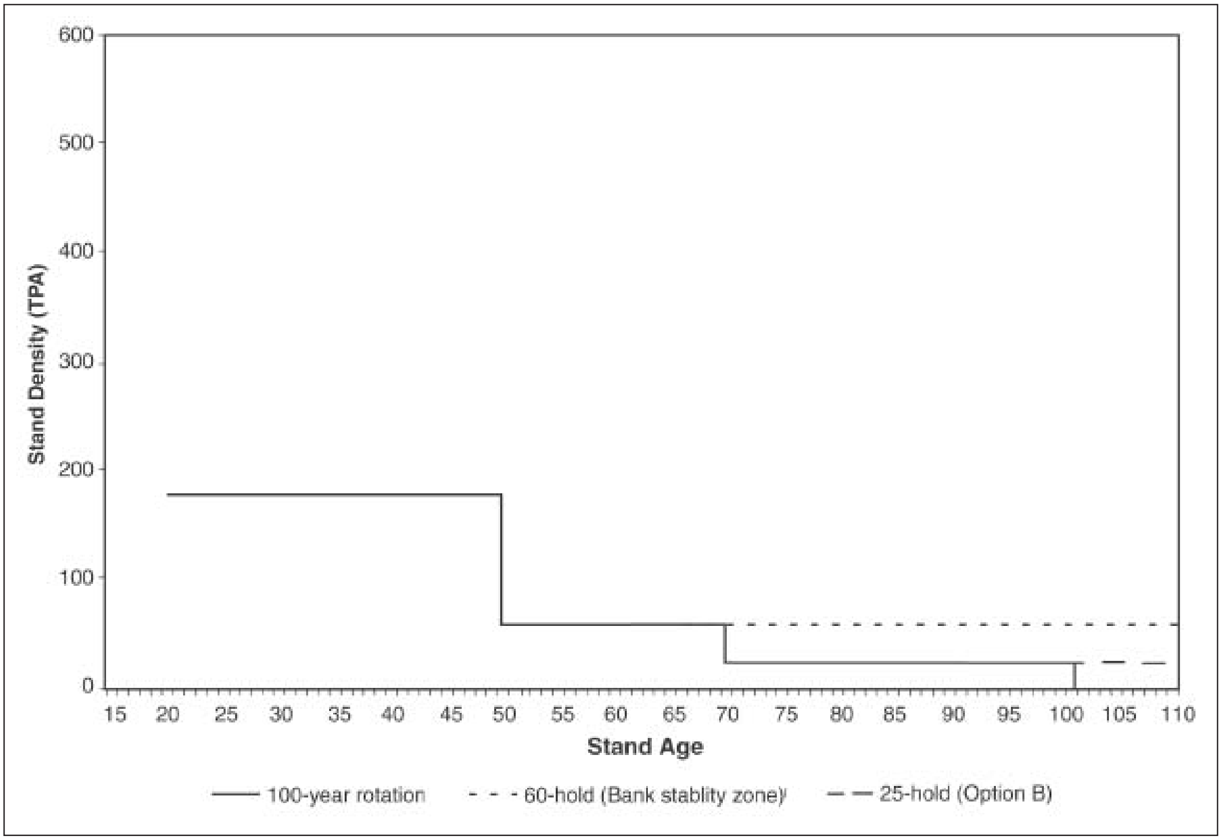

Figure 6—Management diagram for the two template options showing target stand density by stand age. The solid lines show the trajectory of the 100-year rotation, while the dashed lines show the 60-hold density floor for the bank stability zone and the 25-hold density floor for the remainder of the buffer under Option B.

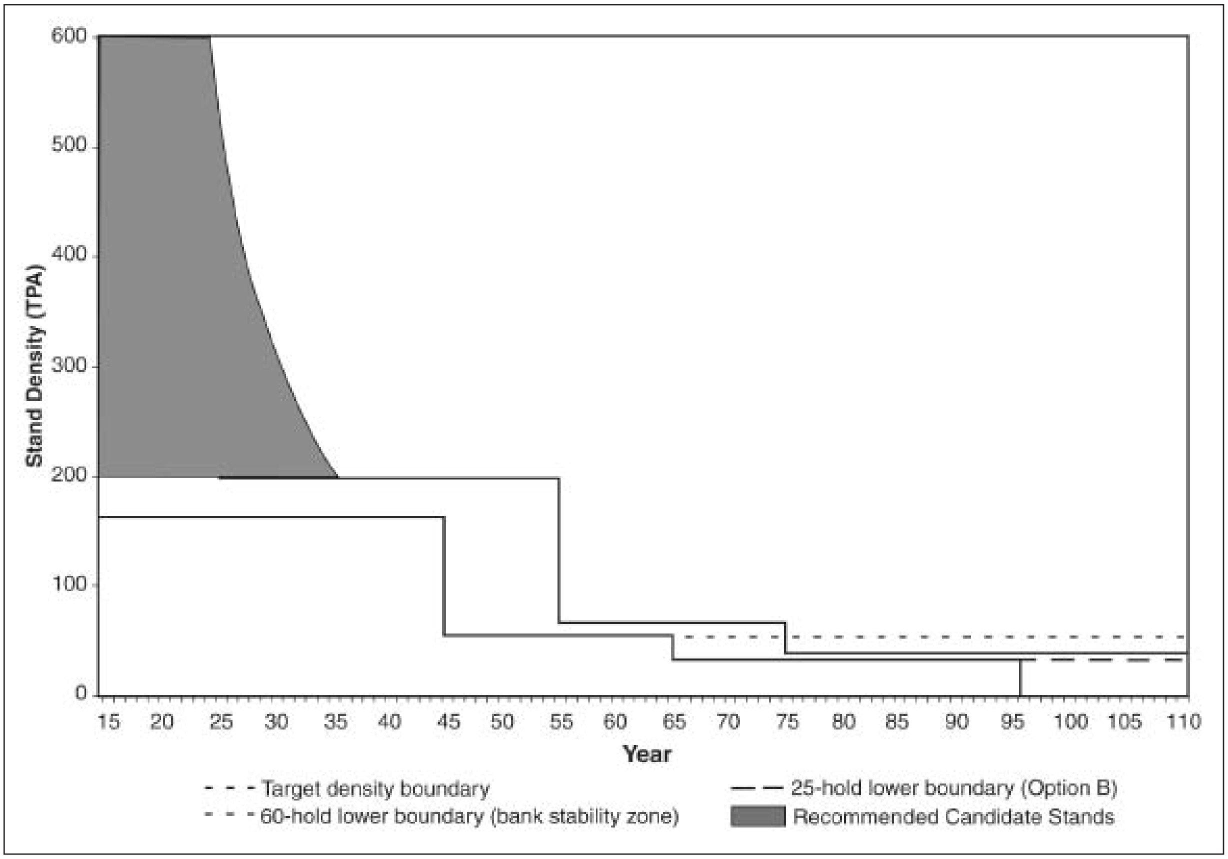

Figure 7—The example management template, with a density range of ± ten percent and a thinning window of ± 5 years for operational and timing flexibility. The shaded region indicates the stand conditions that are best suited for this template. For stands outside of this region, other factors should be considered before applying the template prescription.

allowed a regeneration harvest outside the bank stability zone (100-year prescription). Alternative 11 had a narrower total buffer width of 50 ft but did not allow additional entries after the third commercial thin (25-hold prescription). These alternatives then became Option A and Option B, respectively, in a template that gives landowners a choice between two different approaches (fig. 5).

Stand density targets were plotted by stand age for the two template options in figure 5 to provide a density management diagram (fig. 6). The solid line shows the management trajectory for the 100-year rotation, with the dashed lines showing the 60-hold density floor for the bank stability zone and the 25-hold density floor for the remainder of the buffer under Option B. To refine this prescription into template form, a density range of plus or minus ten percent was added for operational flexibility. Likewise, a 10-year thinning window of plus or minus five years was added for timing flexibility to coordinate with market conditions or other operations. The target density for the third thinning was also increased to 35 TPA, to address concerns that thinning to 25 TPA may be too heavy. The resulting template specifying desired management ranges is shown in figure 7. The shaded area in figure 7 suggests stand conditions which are likely to respond well to the template prescription. Stands beyond this area may be unstable from growing at high densities for too long (Wilson and Oliver 2000) or may not have the capacity to produce a growth response if thinned heavily. Additional factors, such as height/diameter ratio or live crown ratio, should be considered before applying the template prescription to stands beyond the shaded region.

## RIPARIAN TEMPLATE APPLICATIONS

The final riparian management template provides useful guidance for landowners in Washington and Oregon who have overstocked riparian stands and wish to pursue an alternative management plan. For mid-high site stands with conditions that are within the candidate region illustrated in figure 7, the analysis suggests that either of the template options could significantly increase the structural similarity to the DFC over a 140-year time period while also providing an acceptable economic return. Both have been rigorously developed and evaluated by assessment procedures. It should be cautioned, however, that this template has not received regulatory approval. Landowners who wish to implement this template should work with the appropriate agencies to ensure that all regulatory requirements are met. Longer-term permits may also be needed to fully implement the template as a long-term riparian management plan.

The template described serves as an important demonstration of an objective, data-driven process that can be used to develop templates for situations in which desired outcomes (economic and environmental) can be quantified. Additional riparian templates can be developed for different site classes or for hardwood stands. A number of upland applications also exist for templates, including their use to increase biodiversity in intensively managed plantations. It is important to recognize that no single template can provide all biodiversity needs. Rather, a range of different template options is needed for application across a landscape, as applying the same management prescription over a broad region will ultimately decrease the landscape heterogeneity, with a subsequent decrease in diversity (Bunnell and Huggard 1999). An effective template should be broadly applicable in order to be useful over a significant number of acres, while at the same time the range of appropriate template application should be limited, recognizing that one size does not fit all. Finally, a degree of template flexibility will always be necessary to accommodate site-specific needs within a regulatory context.

## UPLAND HABITAT MODELING: A CASE STUDY

The biodiversity pathways discussed above in the context of riparian management alternatives were originally developed with a greater focus on creating upland habitat for species sensitive to the conditions found in older forests such as the spotted owl. The opportunity exists to treat managed stands to provide wildlife habitat for a wide diversity of both game and non-game species. Many types of wildlife habitat models have been developed that can estimate both habitat quality and quantity based on tree lists and forest structure attributes available from existing forest inventory data. There are direct parallels between biodiversity pathway approaches for uplands management and the challenges faced in development of effective riparian strategies. Treatments can be designed to focus on the objectives of a single species or multiple species of local interest while creating a sustainable, albeit diminished, flow of timber.

We illustrate this with a case study carried out to meet the wildlife mitigation agreement on the Satsop Forest in southwestern Washington (Ceder 2001, Marzluff et al. 2002). This project focused on the habitat needs of five species, using previously defined Habitat Suitability Index (HSI) models and the Habitat Evaluation Procedure (HEP) used by Washington Department of Fish and Wildlife (USDI 1980). The species were chosen to track changes in a variety of habitat types: spotted towhee (*Pipilo erythrophthalmus*) in brush habitats; Cooper's hawk (*Accipiter cooperii*) in mixed hardwood and conifer forests; southern red-backed vole (*Clethrionomys gapperi*) in closed canopy forests; pileated woodpecker (*Dryocopus pileatus*) in mature forests; and black-tailed deer (*Odocoileus hemionus columbianus*), a habitat generalist, across a range of structures. The Landscape Management System (LMS) was used with links to the habitat models to estimate current and future habitat conditions responsive to forest growth and alternative management treatments.

Twenty potential management alternatives for Satsop Forest were developed ranging from a no-management control to 40-year regeneration harvests with varying amounts, timings, and levels of thinning between these extremes. Assessments of each alternative determined the amount of habitat for each species and wood volume that could be produced over an 80-year planning horizon. Results indicated the amounts of available habitats, similar to no management or passive management, that could be created through active management (fig. 8). Cooper's hawk, southern red-backed vole, and spotted towhee habitat values changed relatively little as harvesting increased. In contrast, habitat available for the pileated woodpecker, which is associated with older forest structures, generally decreased with high harvest levels but was increased with some management.

Figure 8 shows that reducing the harvest (and timber revenue) by approximately 50 percent can result in increased woodpecker habitat compared to no harvest at all. When the harvest constraints are large, as in this case to affect increases in woodpecker habitat, the incentive needed for private managers to adopt such management approaches with associated costs will also be large. If costly habitat protections are imposed through regulation in absence of compensation, the likelihood of forest conversions on private lands increases.

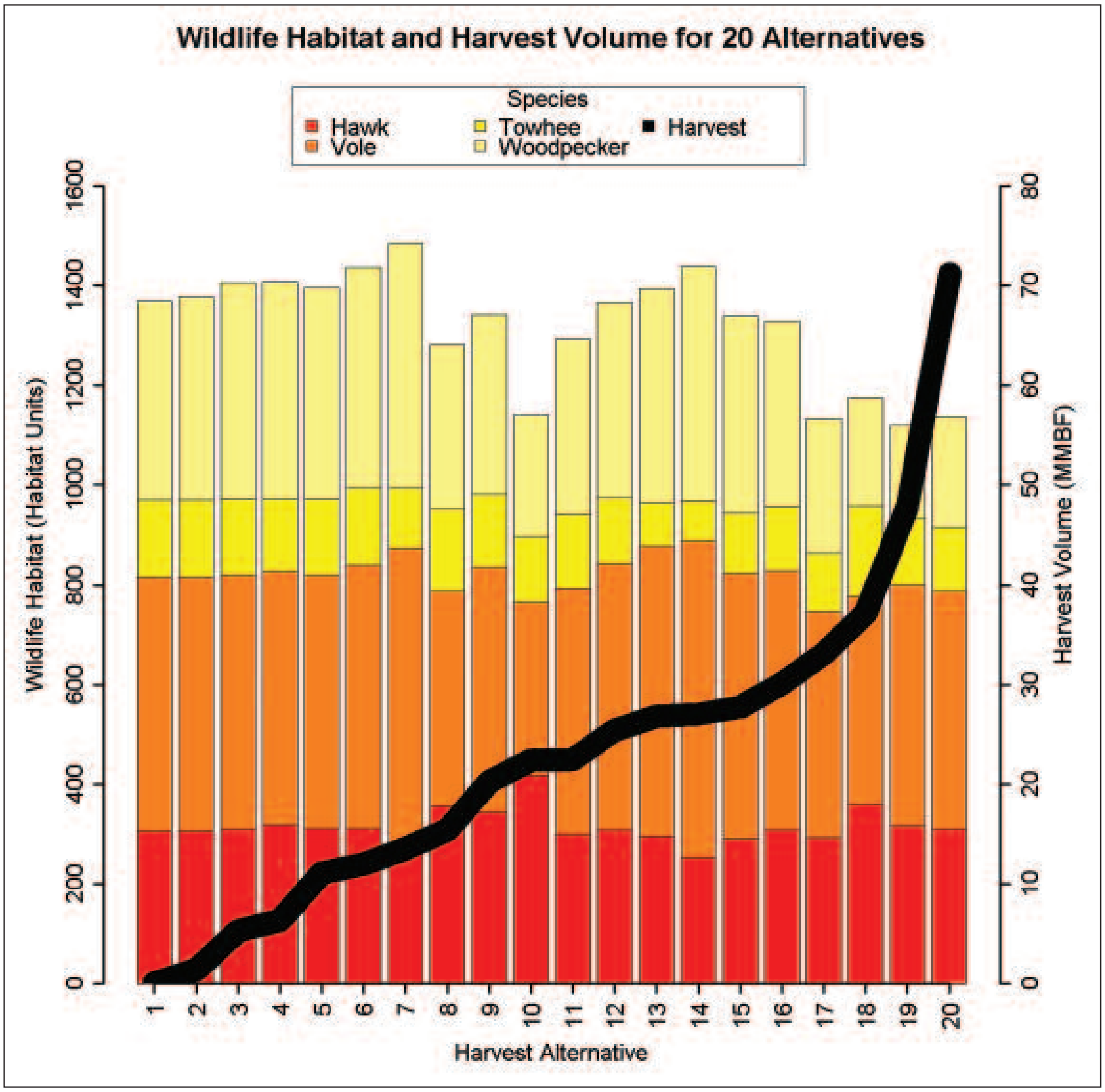

Figure 8—Habitat and volume production for 20 potential 80-year management alternatives for Satsop Forest.

## POTENTIAL NEED FOR ECONOMIC INCENTIVES

To determine the costs of increasing habitat is a straightforward process of comparing the landowner return for alternatives that meet the habitat objectives with those that meet commercial objectives. Determining the societal value of meeting the objectives is more complex and currently a difficult political or regulatory decision. As a simplified example, to aid in understanding the cost, a generic biodiversity pathway including three thinnings and a harvest in 100 years produces an SEV of $420 compared to $1000 for a short commercial rotation involving a single commercial thinning (table 4). This $580 loss to the landowner would require an incentive payment of $29 per acre per year to compensate the owner for their loss. While incentives may be needed for biodiversity pathways, the incentives are substantially less than the compensation needed for a no-harvest reserve which for our example is $81 per acre per year even though it cannot achieve the targeted ecological objective as fast as the biodiversity pathway. If the ecosystem service value of achieving the habitat target is at least $29 per acre per year, society should be willing to provide the incentive for the bio-pathway.

## HABITAT MODEL USES AND LIMITATIONS

There are many habitat models available that are sensitive to forest structure and hence management treatments such as those developed by Johnson and O'Neil (2001).

**Table 4—Soil expectation value (SEV) for commercial and habitat treatments and the incentive needed to offset losses**

| Treatment | SEV/acre | Incentive/ acre/year |
|---|---|---|
| | - - - - - *Dollars* - - - - - - | |
| 50 yr commercial rotation | 1000 | 0 |
| 100 yr biopathway | 420 | 29 |
| No harvest (after stocking) | -615 | 81 |

Empirical models can be derived from tree measures, as with the bird population models of Hansen (1995), who generated regression models relating trees per acre in specific diameter classes to bird population. The Washington State Department of Natural Resources has quantified nesting, roosting, and foraging habitats for the northern spotted owl based on tree and snag measures[7].

Models of choice will be dependent upon the region and species of interest. Appropriate models provide managers and planners with the ability to analyze many alternatives quickly while holding all other assumptions constant. This consistency in assumptions provides uniform comparability between simulations so that relative tradeoffs between treatment alternatives can be assessed.

Key limitations to the use of habitat models include the lack of understory models that are compatible with forest growth models and the need for more research to field-verify the target attributes of habitat models. Understory vegetation is a key component for many wildlife species and associated models. Local understory relative to overstory relationships can be developed to derive mean values for understory measures for each forest cover type, as was done for the Satsop Forest project. Lack of regional models, however, increases the cost and complexity of analysis and limits broader application to inform policy decisions. With these limitations in mind, habitat analysis using available modeling capabilities implemented in LMS, or other forest simulation tools, can provide useful predictive capability to assess habitat availability, risks to habitat, and communicate the potential tradeoffs among different treatments and management strategies. Further, in a modeling framework, outputs developed from habitat analysis can be linked to evaluations of economic impacts expected from management alternatives. Other important public values can be assessed as well, such as forest health and carbon sequestration.

## CONCLUSIONS

Management alternatives employing thinning treatments have been shown to produce old forest structures more effectively and at a lower cost than no-management reserves or buffers. Such alternatives are needed to meet ecological objectives while supporting an acceptable rate of return to discourage land conversion. Management templates based on an exhaustive analysis of simulation alternatives can simplify the identification of best treatments for practical implementation. Analysis of riparian habitat enhancement opportunities has been shown to benefit from similar modeling methodologies as those developed for upland ecosystem management; however, the assessment of tradeoffs between species of greatest interest, the amount of habitat needed, how much revenue can be foregone, and who pays can become complex. Alternatives are being evaluated for reducing costs of habitat enhancement through thinnings but longer rotations to provide the complexity of older forests will not likely be provided by private managers without incentives to compensate for lost revenues.

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