CHAPTER 13AA

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Compositional Trends of Broadscale Cover Types Within the Interior Columbia River Basin

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INTRODUCTION

The composition of broadscale vegetation cover types within a landscape directly affects ecosystem processes and functions. A landscape's composition of vegetation types may have different ecological implications at different scales. Furthermore, landscapes are spatially and temporally dynamic, but the detectability of changes varies by both temporal and geographic scales (Turner and others 1989, Quattrochi and Pelletier 1991). Multi-scale studies of the magnitude and rate in which landscape composition varies improve the predictability of the effects of those changes on ecological processes and functions.

The spatial scale (i.e., grain and extent) in which landscape data is quantified directly influences any inferences derived from that data (Turner 1990). Furthermore, measurements made at different scales may not be comparable (Turner 1990). Hessburg and others (1996) assessed recent historical trends of cover types within the Interior Columbia River Basin (ICRB) using mid-scale data from sampled subwatersheds. Jones and Hann (1996) used a continuous coverage of broadscale vegetation data to assess the change of coarse community types within the ICRB, and within 13 smaller subregions (Ecological Reporting Units; ERUs) of the ICRB over a longer historical time frame. Jones and others (1996) also used that same broadscale vegetation coverage to assess fluxes of those coarse community types within 164 subbasins of the ICRB. They also quantified the departures of communities from expected historical conditions within subbasins to study coarse patterns of vegetation change throughout the ICRB. However, we believed a trend assessment of broadscale cover types within the ICRB was still needed to provide a different context of the potential ecological effects of change.

Cover types are finer-grained elements than the coarser-grained communities assessed by Jones and Hann (1996) and Jones and others (1996). The broadscale cover types are also more comparable to the midscale cover types assessed by Hessburg and others (1996) than the community types assessed by Jones and Hann (1996) and Jones and others (1996). Quantifying vegetation changes using different hierarchical variables at different scales may help to clarify and predict functional responses of the ecosystem.

We discuss the historical change in composition of broadscale cover types throughout the ICRB, and within 13 ERUs within the ICRB (see Jensen and others (1996)for a description and derivation of ERUs). The ERUs have different biophysical compositions (Jensen and others 1996); consequently, they also have different inherent disturbance patterns and processes, as well as variable human-influenced disturbances. By evaluating trends at both the ICRB and ERU scale, we can see if compositional trends were consistent, or varied spatially, across multiple geographic areas.

Three indices of vegetation change are required to better understand the effects of vegetation trends on ecosystem dynamics. The proportional change of a cover type's areal extent (i.e., class change) is valuable because it quantifies the change of that cover type relative to itself. The proportional change of a cover type relative to the landscape (i.e., landscape change) is also insightful, because it factors in the dominance of that type within the landscape. It is quite likely that the availability of a relatively rare cover type may change substantially through time, which may have substantial ecological consequences. However, the proportional change of a rare cover type may not significantly affect the overall composition of the landscape because that cover type only comprised a relatively minor component. Conversely, a seemingly insignificant change of a cover type which dominates a landscape may also have significant ecological ramifications. For example, a 10 percent change in areal extent of a cover type that occupies 80 percent of a landscape will significantly alter the composition of that landscape, as will an 80 percent change of a cover type that comprises 10 percent of the landscape. Even so, substantial changes of a cover type's areal extent may still not have substantial ecological ramifications, if those changes occurred within some expected range of variation in which biological entities and processes have evolved. Consequently, only by comparing the magnitude of change to some historical range of expected conditions can we fully ground the ecological implications of vegetation trends on ecosystem structure and function.

METHODS

Forty one broadscale cover types were mapped at 1-km^2 resolution to describe the current and historical vegetation of the Interior Columbia River Basin (ICRB; Appendix B). The derivation of current and historical vegetation layers was described by Menakis and others (1996). We used two spatial scales and three indices of change to quantify areal changes of cover types between historical and current periods. Compositional changes were assessed across the ICRB as a whole, as well as within 13 ERUs (Figure 1) within the ICRB. These changes were evaluated in respect to the cover type itself (i.e., class change), to the landscape (i.e., ICRB or ERU change), and to the cover type's historical range (i.e., departure index).

Class changes quantified the proportional change of a cover type's area between the historical and current periods. We estimated class change by:

$$CC = ((CTA_C\ !\ CTA_H)'\ CTA_H)*100$$

where CC = percentage of class changed;

CTA_C = current area of cover type;

CTA_H = historical area of cover type;

Landscape changes quantified the areal proportion of the landscape (ICRB or ERU) that was altered as a result of the change in areal extent of a cover type. We estimated landscape change by:

$$LC = ((CTA_C - CTA_H)/LA)*100$$

where LC = percentage of landscape changed;

CTA_C = current area of cover type;

CTA_H = historical area of cover type;

LA = landscape area (ICRB or ERU).

We constructed transition matrices of cover types to further our understanding of class and landscape changes (Jones 1996). The transition matrices tracked the flux of individual 1-km^2 pixels from one cover type to another between the historical and current periods. For example, we wanted to know if a pixel that was classified as a ponderosa pine cover type during the historical period remained ponderosa pine, or changed to another cover type in the current period. The dominant transitions within a landscape (i.e., those affecting at least one percent of the ICRB or ERU) were summarized.

Cover type departure indices were determined by comparing the current areal extent of each type to their modeled 75th and 100th percent historical ranges. Historical ranges of cover types were simulated for the ICRB and individual ERUs using CRBSUM (Columbia River Basin SUccession Model, a spatially explicit, deterministic vegetation simulation model with stochastic properties (Keane 1996). The minimum and maximum values from a single 400-year run of CRBSUM, and outputs for simulation years 0, 50, 100, 200, 300, and 400, were used to define historical ranges. The initial conditions for the historical simulations and the simulation process were described by Menakis and others (1996) and Long and others (1996), respectively. We then calculated the 75th percent historical mid range by adding or subtracting 12.5 percent of the historical range to the historical minimum and historical maximum, respectively. Five departure classes were defined based on the relationship between the current area of each cover type to its simulated 75th and 100th percent historical ranges (Table 1, Figure 2).

We used class changes, landscape changes, and departure indices to determine ecologically significant changes of cover types. We judged the absolute value of class changes $\geq$ 20 percent and landscape changes $\geq$ 1.0 percent as ecologically significant, but only if the departure indices indicated that the current area of the cover type occurred above or below its 75th percent historical mid range (i.e., departure classes 1, 2, 4, and 5). In turn, areal changes resulting in departures classes 1, 2, 4, and 5, were ecologically significant if either the historical or current areas of a cover type exceeded one percent of the landscape, and the class change exceeded five percent.

The herbaceous wetlands, shrub wetlands, and aspen cover types appeared to be under-represented in the historical vegetation layer and over-represented in the current layer. These types, which generally occur in scattered, relatively small- to medium-sized patches, tend to be under-estimated as mapping resolution increases (Turner and others 1996). Consequently, in that the historical vegetation layer was developed at a coarser resolution than the current vegetation layer (Menakis and others 1996), it is likely that the two mapping efforts contained different biases. In fact, rectification with the potential vegetation types indicated that the herbaceous wetlands, shrub wetlands, and aspen cover types were likely more abundant on the historical landscape than our data indicated (see Appendix A, and Menakis and others (1996) for a description of potential vegetation types, and the derivation of the historical vegetation layer). We did not report the changes of these three types because they could not be accurately quantified.

RESULTS

Interior Columbia River Basin

The richness of cover types increased between historical and current periods due to the addition of three anthropogenic cover types (urban, cropland, and exotic forbs/annual grass; Table 2). We did not detect measurable changes in areal extent of the alpine tundra, barren, Oregon white oak, red fir, or water cover types. Ecologically significant changes were detected for 66 and 34 percent of the cover types relative to class and the ICRB, respectively. Of these, nine had negative trends (Agropyron bunchgrass, big sagebrush, cottonwood/willow, fescue bunchgrass, Interior ponderosa pine, mountain big sagebrush, western larch, western white pine, and whitebark pine), and 6 had positive trends (cropland/hay/pasture (hereafter croplands), exotic forbs/annual grass, grand fir/white fir, Interior Douglas-fir, juniper/sagebrush, and shrub or herb/tree regen). Two cover types (western white pine and whitebark pine/alpine larch were virtually eliminated between historical and current periods ($\geq$ 95 percent decline). Only the antelope bitterbrush/bluebunch wheatgrass (hereafter bitterbrush/bluebunch wheatgrass), barren, and lodgepole pine cover types occurred within their historical mid ranges during the current period.

Transition matrices indicated that agricultural development was largely responsible for the substantial areal declines of the fescue bunchgrass, Agropyron bunchgrass, big sagebrush, and native forb cover types. Similarly, nearly 12 percent of the mountain big sagebrush type was also converted to agricultural types, although most of its decline was attributable to the encroachment of the juniper/sagebrush type. Other major changes that occurred in non-forest cover types were dominated by the invasion of exotic species. The increase in the exotic forbs/annual grass cover type occurred at the expense of big sagebrush, and to lesser extents to Agropyron bunchgrass, mountain big sagebrush, and fescue bunchgrass cover types.

Our observed changes of forest cover types were dominated by the transitions of early-seral, shade-intolerant tree species to shade-tolerant tree species. For example, the areal decline of the Interior ponderosa pine cover type was attributable to increasing areas of the grand fir/white fir and Interior Douglas-fir cover types; areal declines of the western larch cover type was due to an increase of Douglas-fir, lodgepole pine, or grand fir/white fir cover types; a large proportion of the western white pine cover type was converted to the grand fir/white fir type; and a large proportion of the whitebark pine type was converted to the Engelmann spruce/subalpine fir cover type.

Blue Mountains ERU

Cover type richness decreased from 24 to 23 types within the Blue Mountain ERU between historical and current periods (Table 3). Although three anthropogenic cover types appeared (cropland, exotic forbs/annual grass, and urban) in the current period, four endemic cover types were lost (bitterbrush/bluebunch wheatgrass, cottonwood/willow, western larch, and whitebark pine/alpine larch).

We detected ecologically significant trends of 56 and 42 percent of the cover types relative to class and the Blue Mountains ERU, respectively (Table 3). Only the alpine tundra, Interior Douglas-fir, mountain mahogany, native forb, and water cover types occurred within their historical mid ranges during the current period. However, the departures of eight cover types were not ecologically significant.

The cover type composition within the Blue Mountains ERU was most affected by areal increases of the croplands and grand fir/white fir cover types, and areal declines of the fescue bunchgrass and Interior ponderosa pine types. The cover type transition matrix indicated that 41 percent of the fescue bunchgrass type was converted to the croplands cover type. Other areas converted to agricultural uses were derived predominantly from the big sagebrush, mountain big sagebrush, and Agropyron bunchgrass types. The transition matrix also indicated that the loss of the Interior ponderosa pine cover type was mostly attributable to a conversion into the grand fir/white fir type, and to a lesser degree, the Interior Douglas-fir cover type.

Central Idaho Mountains ERU

We detected an increase of cover type richness within the Central Idaho Mountains ERU between historical and current periods (Table 4). Although three endemic cover types (bitterbrush/bluebunch wheatgrass, native forb, and whitebark pine/alpine larch) were eliminated, five additional cover types appeared during the current period. Three of the five new cover types detected in the current period were anthropogenic (croplands, exotic forbs/annual grass, and urban). Ecologically significant trends relative to class and the Central Idaho Mountains ERU were detected for 55 and 36 percent of the cover types, respectively. Similarly, the departures of 39 percent of the cover types from their historical mid ranges were ecologically significant.

The Central Idaho Mountains ERU was dominated by the areal declines of the Agropyron bunchgrass and Interior Douglas-fir cover types, and the increased areal extent of the croplands, Engelmann spruce/subalpine fir, grand fir/white fir, and shrub or herb/tree regen cover types (Table 4). Approximately 53 percent of the Douglas-fir type was converted to primarily shrub or herb/tree regen, lodgepole pine, Engelmann spruce/subalpine fir, and grand fir/white fir cover types. Similarly, the substantial areal decline of the Agropyron bunchgrass cover type was primarily a result of conversions into the mountain big sagebrush (34 percent), big sagebrush (20 percent), or croplands (19 percent) cover types.

Columbia Plateau ERU

Between historical and current periods, five additional cover types were created while three were eliminated from the Columbia Plateau ERU (Table 5). The three cover types eliminated included trace amounts of the native forb, western white pine, and whitebark pine/alpine larch cover types. The five cover types that appeared during the current period include three anthropogenic types (croplands, exotics/annual grass, and urban) and trace amounts of the mountain hemlock and western redcedar/western hemlock types.

We detected ecologically significant trends relative to class and the Columbia Plateau ERU for 49 and 20 percent of the cover types, respectively (Table 5). Similarly, eight of 35 cover types had significant departures from their historical mid ranges. Conversely, nine cover types (alpine tundra, bitterbrush/bluebunch wheatgrass, cottonwood/willow, Interior Douglas-fir, Interior ponderosa pine, mixed-conifer woodlands, mountain hemlock, water, and western larch) occurred within their historical mid ranges during the current period.

Cover type transitions within the Columbia Plateau ERU were dominated by the agricultural conversion of 46 percent of the big sagebrush, 79 percent of the Agropyron bunchgrass, and 91 percent of the fescue bunchgrass cover types. In fact, the croplands cover type comprised nearly 45 percent of the Columbia Plateau ERU during the current period.

Lower Clark Fork ERU

The richness of cover types within the Lower Clark Fork ERU increased from 17 to 20 types between historical and current periods (Table 6). Although two types (mixed-conifer woodlands and whitebark pine/alpine larch) were eliminated during this period, five new types (croplands, exotics/annual grass, urban, mountain hemlock, and western redcedar/western hemlock) appeared within the Lower Clark Fork ERU.

We detected ecologically significant trends for 41 and 36 percent of the cover types relative to class and the Lower Clark Fork ERU, respectively (Table 6). Only three cover types (Engelmann spruce/subalpine fir, Interior Douglas-fir, and western larch) occurred within their historical mid ranges during the current period. Although we detected substantial departures for the other 19 cover types, only seven of them were ecologically significant.

The compositional changes of cover types which affected the Lower Clark Fork ERU to the greatest extent involved areal increases of the grand fir/white fir and shrub or herb/tree regen cover types, and areal declines of the Interior ponderosa pine and western white pine cover types. The areal extent of the grand fir/white fir cover type increased by nearly 6000 percent and dominated the ERU during the current period. Conversely, the western white pine cover type was nearly eliminated from approximately 27 percent of the Lower Clark Fork ERU. Cover type transitions were dominated by the near total conversion of the western white pine cover type to grand fir/white fir, western larch, and shrub or herb/tree regen cover types, and the conversion of 66 percent of the Interior ponderosa pine cover type to the grand fir/white fir type.

Northern Cascades ERU

The richness of cover types within the Northern Cascades ERU increased from 29 to 32 types between historical and current periods (Table 7). During this period, three anthropogenic types appeared, while the trace amount of the salt desert shrub type was eliminated.

We detected ecologically significant trends in respect to class and the Northern Cascades ERU for 55 and 40 percent of the cover types respectively (Table 7). Of the 33 cover types detected within the ERU, only the chokecherry/serviceberry/rose, Interior ponderosa pine, water, and whitebark pine/alpine larch cover types occurred within their historical mid ranges during the current period. However, nearly 50 percent of the substantial departures from the historical mid range were not ecologically significant.

The compositional changes of cover types in the Northern Cascades ERU were dominated by the areal decline of the Engelmann spruce/subalpine fir, Interior ponderosa pine, western larch, and whitebark pine cover types, and the areal increase of the croplands, lodgepole pine, and Pacific silver fir/mountain hemlock cover types. The transition matrix indicated that the Engelmann spruce/subalpine fir cover type converted primarily to the Pacific silver fir/mountain hemlock and lodgepole pine cover types; the Interior ponderosa pine cover type converted to either grand fir/white fir or Interior Douglas-fir cover types; western larch converted into Interior Douglas-fir; and whitebark pine converted into Engelmann spruce/subalpine fir. Similarly, the areal increase of the croplands cover type occurred primarily at the expense of the big sagebrush and fescue bunchgrass cover types.

Northern Glaciated Mountains

The richness of cover types increased from 24 to 27 types between historical and current periods in the Northern Glaciated Mountains ERU (Table 8). Four additional cover types appeared (croplands, exotics/annual grass, urban, and western redcedar/western hemlock), while the whitebark pine/alpine larch cover type was eliminated during that time frame. In addition to the whitebark pine/alpine larch cover type, nearly all of the big sagebrush and cottonwood/willow types were eliminated between historical and current periods.

Ecologically significant trends relative to class and the Northern Glaciated Mountains occurred in 46 percent of the cover types (Table 8). Of the 28 cover types detected in the ERU, the areal extents of only the bitterbrush/bluebunch wheatgrass, Engelmann spruce/subalpine fir, mixed-conifer woodlands, and mountain hemlock cover types occurred within their historical mid ranges. Although we detected substantial departures from their historical mid ranges for most cover types, only 54 percent of the departures were ecologically significant relative to the composition of types within the Northern Glaciated ERU.

The composition of the Northern Glaciated Mountains ERU was affected predominantly by the areal increase of the croplands, grand fir/white fir, and Interior Douglas-fir cover types, and areal declines of the fescue bunchgrass, Interior ponderosa pine, and western larch cover types (Table 8). The transition matrix indicated that agricultural development was largely responsible for the areal declines of the big sagebrush, fescue bunchgrass, and Interior ponderosa pine cover types. Similarly, 46 percent of the western larch and 33 percent of the Interior ponderosa pine cover types were converted to either grand fir/white fir or Interior Douglas-fir types.

Northern Great Basin ERU

The richness of cover types did not vary between historical and current periods within the Northern Great Basin ERU (Table 9). However, three cover types appeared (croplands, exotics/annual grass, and grand fir/white fir), while three cover types (native forb, Sierra Nevada mixed-conifer, and western larch) were eliminated during that time interval.

We detected ecologically significant class trends of 10 cover types (Table 9). However, ecologically significant changes relative to the Northern Great Basin ERU occurred due to the changes of four cover types (big sagebrush, croplands, exotics forbs/annual grass, and mountain big sagebrush). The current areal extent of most (84 percent) cover types departed substantially from their historical mid ranges. However, only the departures of five cover types (croplands, exotic forbs/annual grass, fescue-bunch grass, juniper sagebrush, and mountain big sagebrush) were ecologically significant.

The compositional changes of the Northern Great Basin ERU were dominated by the areal increase of the croplands and exotic forbs/annual grass cover types, and the areal decline of the big sagebrush, mountain big sagebrush, and salt desert shrub cover types (Table 9). Agricultural development was largely responsible for the substantial decline of the salt desert shrub cover type, and relatively smaller declines of the Agropyron and fescue bunchgrass cover types. The increase of the exotic forbs/annual grass cover type occurred predominantly in the big sagebrush, and to a lesser extent, the mountain big sagebrush, cover types.

Owyhee Uplands ERU

The richness of cover types within the Owyhee Uplands ERU increased from 23 to 27 types between the historical and current periods (Table 10). Six cover types appeared, while two cover types (lodgepole pine and native forb) disappeared during this time interval.

We detected ecologically significant trends of 58 and 10 percent of the cover types relative to class and the Owyhee Uplands ERU, respectively (Table 10). Although the areal extents of seven of 29 cover types occurred within their historical mid ranges during the current period, the departures of only six types were ecologically significant.

The composition of the Owyhee Uplands ERU was affected to the greatest extent by the areal decline of the big sagebrush cover type, and the areal increase of the croplands cover type (Table 10). Not surprisingly, the transition matrix indicated that agricultural development was responsible for the substantial reduction in area of the big sagebrush cover type. Although we observed a 21 percent decline of the big sagebrush cover type across 11 percent of the Owyhee Uplands ERU, the big sagebrush type still occurred within its historical mid range during the current period.

Snake Headwaters ERU

The richness of cover types within the Snake Headwaters ERU decreased from 25 to 24 types between the historical and current periods (Table 11). Although three anthropogenic types (croplands, exotic forbs/annual grass, and urban) appeared, four endemic cover types (chokecherry/serviceberry/rose, cottonwood/willow, mixed-conifer woodlands, and native forb) were eliminated within this time interval.

Of the 28 cover types observed within the Snake Headwaters ERU, we detected ecologically significant trends for 46 and 29 percent of the types relative to class and the Snake Headwaters ERU, respectively (Table 11). Although we observed substantial departures from the historical range in all but five cover types, these departures were ecologically significant for only 35 percent of the types.

The composition of cover types within the Snake Headwaters ERU was affected predominantly by the areal increase of the croplands and Interior Douglas-fir cover types, and the areal decline of the big sagebrush and lodgepole pine, and to a lesser degree, the mountain big sagebrush, and shrub or herb/tree regen cover types (Table 11). The areal increase of the Interior Douglas-fir cover type was derived mostly from lodgepole pine, mountain big sagebrush, shrub or herb tree/regen, and Engelmann spruce/subalpine fir cover types. The 67 percent loss of the lodgepole pine cover type was attributable to gains in the Interior Douglas-fir and Engelmann spruce/subalpine fir cover types. Nearly all of the big sagebrush and mountain big sagebrush cover types were eliminated within the Snake Headwaters ERU. Agricultural conversion was responsible for the 84 percent areal decline of the big sagebrush cover type, whereas encroaching Douglas-fir converted 89 percent of the mountain big sagebrush cover type.

Southern Cascades ERU

Overall, the richness of cover types increased from 33 to 34 cover types within the Southern Cascades ERU between historical and current periods (Table

12). Four cover types appeared (croplands, exotic forbs/annual grass, urban, and mountain mahogany), while three cover types disappeared (cottonwood/willow, salt desert shrub, and Sierra mixed-conifer) during this time interval. In addition, nearly all of the western larch cover type was eliminated between the historical and current periods.

We detected ecologically significant trends relative to class and the Southern Cascades ERU with 42 and 24 percent of the cover types, respectively (Table 12). Six cover types (alpine tundra, barren, chokecherry/serviceberry/rose, Engelmann spruce/subalpine fir, mixed-conifer woodlands, and Pacific silver fir/mountain hemlock) occurred within their historical mid ranges during the current period. Although we observed substantial departures from the historical mid ranges for most cover types, only the departures of 30 percent of the types were ecologically significant relative to the composition of the Southern Cascades ERU.

The composition of the Southern Cascades ERU was predominantly affected by the decline of the Interior ponderosa pine cover type, and increase of the croplands, Interior Douglas-fir, and grand fir/white fir cover types (Table 12). The transition matrix indicated that approximately 30 percent of the Interior ponderosa pine cover types changed into Interior Douglas-fir and grand fir/white fir cover types. The transitions of non-forest cover types were dominated by the agricultural conversion of the big sagebrush cover type.

Upper Clark Fork ERU

The richness of cover types within the Upper Clark Fork ERU increased from 21 to 24 types between the historical and current periods (Table 13). Five additional cover types appeared (croplands, exotic forbs/annual grass, urban, mountain mahogany, and western white pine), while two cover types (juniper/sagebrush and whitebark pine/alpine larch) were eliminated during this time interval. The western larch cover type was nearly eliminated during this period as well.

We observed ecologically significant trends relative to class and the Upper Clark Fork ERU with 46 percent and 38 percent of the cover types, respectively (Table 13). Six of 26 cover types occurred within their historical mid ranges during the current period. The departures of 38 percent of the cover types were ecologically significant.

The composition of the Upper Clark Fork ERU was most affected by the areal increase of the croplands and Engelmann spruce/subalpine fir cover types, and the areal decline of the Agropyron bunchgrass, fescue bunchgrass, and Interior Douglas-fir cover types (Table 13). The transition matrix indicated that approximately 18 percent of the fescue bunchgrass and 69 percent of the Agropyron bunchgrass cover types were converted by agricultural development between historical and current periods. An additional 47 percent of the fescue bunchgrass cover type was eliminated by the encroachment of Interior ponderosa pine and Interior Douglas-fir cover types. Changes of forest cover types were dominated by transitions of the lodgepole pine and Interior Douglas-fir cover types into the Engelmann spruce/subalpine fir cover type.

Upper Klamath ERU

Although the richness of cover types within the Upper Klamath ERU did not change between the historical and current periods, the composition of cover types changed substantially (Table 14). During the temporal period covered by our analysis, three anthropogenic cover types appeared, while three endemic cover types (salt desert shrub, western larch, and whitebark pine/alpine larch) were eliminated.

We detected ecologically significant trends relative to class and the Upper Klamath ERU for 48 and 30 percent of the cover types, respectively (Table 14). During the current period, the areal extent of only six cover types (alpine tundra, barren, chokecherry/serviceberry/rose, Engelmann spruce/subalpine fir, mixed-conifer woodlands, and shrub or herb/tree regen) occurred within their historical mid ranges. Although we observed substantial departures of most cover types from their historical mid ranges, only the departures of 36 percent of the cover types were ecologically significant.

The Upper Klamath ERU's composition was predominantly affected by the areal increase of the croplands and Interior Douglas-fir cover types, and the areal decline of the fescue bunchgrass and Interior ponderosa pine cover types (Table 14). The transition matrix indicated that the 95 percent decline of the fescue bunchgrass cover type that we observed was a result of transitions to the Interior ponderosa pine (94 percent), croplands (33 percent), and mixed-conifer woodlands (17 percent) cover types. Nearly 25 percent of the Interior ponderosa pine cover type changed into the Interior Douglas-fir cover type. Although somewhat less significant in respect to the Upper Klamath ERU, the transition matrix suggested that approximately 56 percent of the mountain big sagebrush and 99 percent of the low sagebrush cover types changed into the juniper/sagebrush cover type.

Upper Snake ERU

The richness of cover types within the Upper Snake ERU increased from 23 to 24 types between the historical and current periods (Table 15). Three anthropogenic cover types appeared, and two endemic cover types (mixed-conifer woodlands and native forb) were eliminated during the period covered by our analysis.

We detected ecologically significant trends relative to class and the Upper Snake ERU with 35 and 23 percent of the cover types, respectively (Table 15). Although only six of 26 cover types occurred within their historical mid range during the current period, most departures were not ecologically significant. Ecologically significant departures were evident with 27 percent of the cover types.

The composition of cover types within the Snake Headwaters ERU was primarily influenced by the changes of three cover types (Table 15). A significant decline of the big sagebrush cover type occurred across 42 percent of the ERU, whereas areal increases of the croplands and exotic forbs/annual grass cover types affected nearly 43 percent of the ERU. Forty-one percent of the areal decline of the big sagebrush cover type was a result of agricultural development. Lesser amounts of this type were converted into the exotic forbs/annual grass (10 percent) and Agropyron bunchgrass (5 percent) cover types. Virtually all of the areal increase of the croplands cover type occurred at the expense of the big sagebrush cover type.

DISCUSSION

Differing geographic scales did not seem to substantially affect cover type trends within our assessment area. That is, the cover type trends observed within the 13 ERUs generally reflected the trends that occurred within the ICRB as a whole. Furthermore, with the exception of the bitterbrush/bluebunch wheatgrass, Engelmann spruce/subalpine fir, lodgepole pine, and shrub or herb/tree regen cover types, there was little variability of the cover type departure classes among the 13 ERUs. Although the departure classes of the bitterbrush/bluebunch wheatgrass, Engelmann spruce/subalpine fir, and lodgepole pine varied among the ERUs, the ERUs that seemed to have the most conflicting trends were those whose departures were not ecologically significant. For example, the departure classes of the lodgepole pine cover type indicated that it generally occurred within or above its historical mid range for the majority of ERUs. Conversely, the current areal extent of lodgepole pine within the Columbia Plateau, Northern Great Basin, Snake Headwaters, and Upper Snake ERUs was well below their historical mid range. However, only the observed departure class of the Snake Headwaters ERU was ecologically significant. The shrub or herb/tree regen cover type occurred well above its historical mid range in four ERUs, within its historical mid range in six ERUs, and well below its historical mid range in three ERUs.

Agricultural development significantly changed the composition of cover types within the ICRB, and within all of the 13 ERUs. Approximately 16 percent of the ICRB has been converted to the croplands cover type. Even the least impacted ERUs (e.g., Lower Clark Fork and Northern Great Basin) lost two to three percent of their area to agricultural uses. Conversely, agricultural development occurred across 33 and 45 percent of the Upper Snake and Columbia Plateau ERUs. Not surprisingly, most of the agricultural conversions occurred within non-forest cover types, and were largely responsible for the significant areal declines of the endemic grassland and forb cover types (i.e., Agropyron bunchgrass, fescue bunchgrass, native forbs), and also for a large proportion of the observed declines in many shrubland cover types (e.g., big sagebrush, mountain big sagebrush, salt desert shrub).

Within forest environments, cover type compositional changes were predominantly related to the replacement of cover types dominated by shade-intolerant species resistant to fire, insects and disease, by those dominated by shade-tolerant species having higher susceptibilities to fires, insects, and diseases. With few exceptions, we observed significant declining trends of the cottonwood/willow, Interior ponderosa pine, western larch, western white pine, whitebark pine/alpine larch, and whitebark pine cover types throughout the ICRB. Conversely, we commonly detected significant increases of the grand fir/white fir, Interior Douglas-fir, and western redcedar/western hemlock cover types. These trends were most likely brought about by fire suppression and timber harvesting activities. Fire suppression increased the establishment and development of forest stands comprised of shade-tolerant species. Conversely, past silvicultural practices commonly targeted the early-seral, shade-intolerant species for removal from forest stands.

We detected 37 occurrences in which 12 cover types were eliminated from the ERUs between historical and current periods. Although these types disappeared from our broadscale coverage of the current period, we do not suggest that they no longer occur on the landscape. That is to say, their areal declines were to the extent that the cover types no longer represented a dominant component of a 1-km^2 pixel. In all likelihood, a finer-grained analysis would detect their presence in the landscape (Henderson-Sellers and others 1985, Meentemeyer and Box 1987). The cover types that disappeared most frequently included whitebark pine/alpine larch (lost from seven ERUs), native forb (lost from six ERUs), and western larch (lost from five ERUs). The cover types that disappeared were commonly rare within an ERU, historically. In most instances (76 percent), the historical area of the eliminated cover type comprised less than 0.5 percent of an ERU ($\underline{x}$ = 1.10 percent, $\underline{sd}$ = 4.40). However, the western white pine cover type was lost from the Lower Clark Fork ERU even though it comprised nearly 27 percent of landscape during the historical period. Four of the 12 cover types (native forb, Sierra mixed-conifer, western white pine, and whitebark pine/alpine larch) that frequently disappeared from various ERU landscapes, had experienced at least 80 percent declines within the ICRB as a whole.

We compared the trends of our broadscale forest and woodland cover types within ERUs to the trends of midscale forest and woodland cover types reported by Hessburg and others (1996). As expected, there were some discrepancies between the two data sets. However, considering the two analyses were conducted at different resolutions (1-km2 and 4-ha for broadscale and midscale, respectively), and assessed trends across different time periods (approximately 100 to 150 years versus the past 30 to 70 years for broadscale and midscale, respectively), the observed trends were quite comparable. The most common discrepancies between the two analyses included instances in which significant broadscale trends were detected, whereas significant midscale trends were not. These sorts of discrepancies occurred most frequently with the grand fir/white fir, lodgepole pine, and western larch cover types, and within the Central Idaho Mountains, Lower Clark Fork, and Southern Cascades ERUs. Conflicting trends (i.e., the broadscale and midscale analyses detected opposite trends) most commonly occurred with the Engelmann spruce/subalpine fir and Interior ponderosa pine cover types.

Coarse-grained analyses commonly underestimate types occurring in small to medium-sized patches that do not dominate the spectral response of a particular pixel (Quattrochi and Pelletier 1991). We already noted the problems we had with accurately depicting the presence of the aspen, herbaceous wetlands, and shrub wetlands cover types. Our broadscale mapping of vegetation types also underestimated the extent of plant communities dominated by exotic species. For example, many of the broadleaf forb exotics (e.g., knapweeds, yellow starthistle, leafy spurge) typically occur in patches too small to dominate a 1-km^2 pixel. In addition, we were more likely to detect large patches of communities dominated by exotic annual grasses (e.g., cheatgrass and medusahead) where they occurred as a monoculture. When exotic grasses occurred as an understory component of a shrubland community, the spectral image was typically classified as a shrub cover type (e.g., big sagebrush, mountain big sagebrush). Lastly, even if a patch was large enough to be detected, remote sensing techniques are currently not capable of differentiating endemic species from exotic species.

Many cover types often incurred substantial class changes, but because they comprised relatively minor proportions of the landscape, their changes did not significantly affect the overall composition of the landscape. However, that is not to say that their changes did not have significant effects on other components of the ecosystem, or various ecosystem functions. Relatively rare vegetation communities may contain unique phenotypes and genotypes which may be important for individual, population, and species fitnesses, and consequently, evolutionary processes.

Our historical simulation of cover types suggested that the composition of types within an ERU was relatively dynamic. Each ERU contained two to four cover types for which we detected substantial trends between the historical and current period, but which still occurred within their historical mid range during the current period. Thus, substantial changes of at least some broadscale cover types seems to have been the norm, rather than the exception, prior to European settlement within the ICRB. The cover types which appeared to be most dynamic across a landscape included Engelmann spruce/subalpine fir, Interior Douglas-fir, Interior ponderosa pine, shrub or herb/tree regen, mixed-conifer woodlands, western larch, fescue bunchgrass, and bitterbrush/bluebunch wheatgrass.

Inherent to any scale of analysis is the need to summarize data to some geographic unit. For our analysis of broadscale cover types, we chose to summarize composition and trends at the ERU and ICRB levels. We do not imply that the trends we observed would necessarily occur at other analysis scales. In fact, our transition analyses indicated that different proportions of pixels of a particular cover type either stayed the same between historical and current periods, or were converted into another cover type. Similarly, other pixels of other cover types may have converted into our cover type of interest. In other words, the transitions of cover types were spatially variable throughout a given landscape. Consequently, the trends we observed at either the ICRB or ERU level likely vary within smaller units of those same areas. For example, in some areas the trend may have been up; other areas may have had a downward trend; whereas some areas may have had no apparent trend at all.

SUMMARY

We detected significant trends in most broadscale cover types within the Interior Columbia River Basin. Although the areal extent of many cover types changed substantially, the trends were not always expected to have ecologically significant effects on ecosystem functions, as the trends appeared to occur within the normal range of variability for a particular landscape.

Anthropogenic cover types (i.e., croplands, exotic forbs/annual grass, and urban) were commonly added to the landscape between the historical and current periods. The endemic cover types which were lost from various geographic areas within this time, commonly comprised relatively small proportions of the landscape historically. In non-forested environments, the transitions of cover types were dominated by conversions in land uses attributable to the agricultural development of the endemic grasslands and shrublands. In forested environments, the changes of cover types seemed mostly attributable to the synergistic effects of fire suppression and timber harvesting activities. Overall, we observed an increasing trend of forest cover types dominated by shade-tolerant species that are generally more susceptible to fires, insects and pathogens, and a declining trend of forest cover types dominated by shade-intolerant species that are more resistant to fire, insects, and pathogens.

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Table Captions

Table 1--Cover type departure classes.

Figure Captions

Figure 1--Ecological reporting units of the Interior Columbia River Basin.

Figure 2--Relationship between current areal extent of broadscale cover types and their respective historical ranges.

Table 1--Cover type departure classes.

Departure Class	Relationship of current area to historical ranges
1	A_c[1] < Historical Minimum
2	Historical Minimum $\leq A_c$ <-75% Historical mid range
3	A_c is within 75% historical mid range
4	75% Historical mid range < $A_c \leq$ Historical Maximum
5	A_c > Historical Maximum

[1]A_c = Current area.

Figure 1 not available

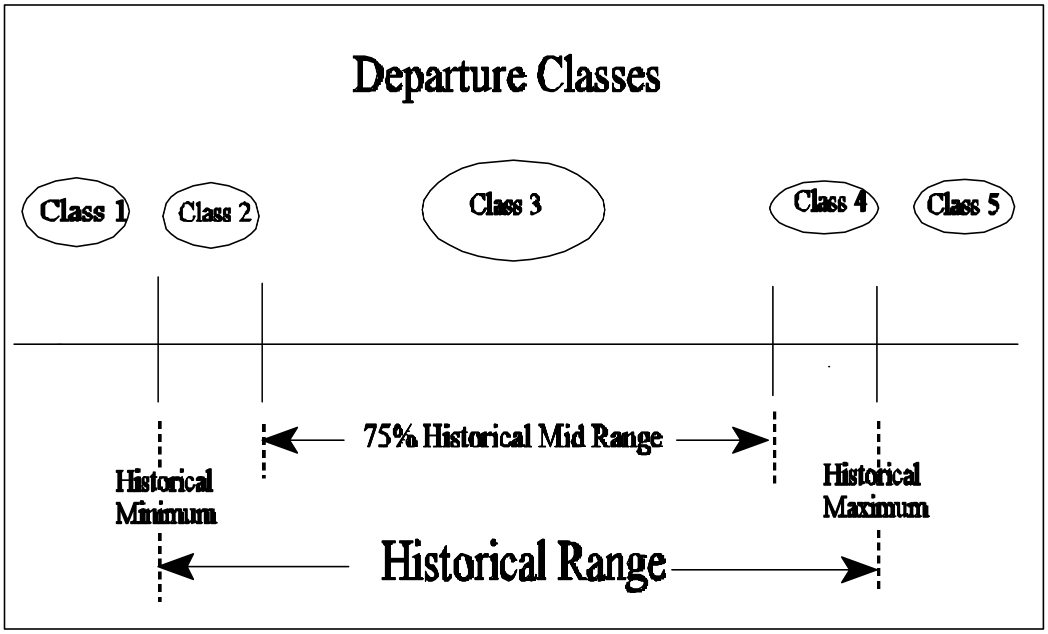

Figure 2--Relationship between current areal extent of broadscale cover types and their respective historical ranges.