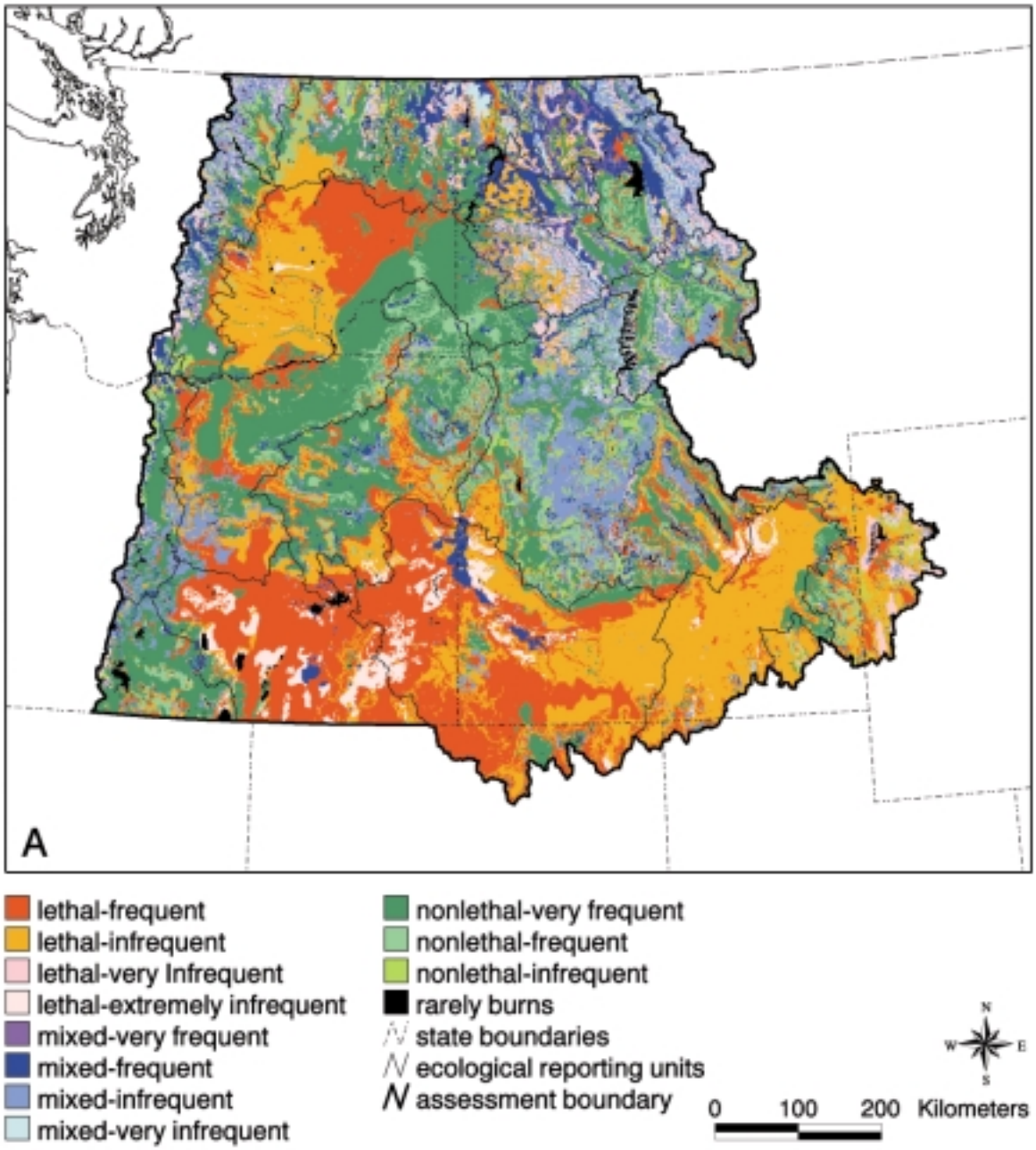
three possible explanations: (1) ongoing insect, pathogen, and fire disturbances exerted a greater mortality influence on overstory structure than we had anticipated, such that large tree structure was not dominant; (2) some areas were affected by partial cutting before the time of our historical coverage, and we were not able to determine by remote sensing any associated road, skid trail, or harvest signature; and (3) some structures classified as young multistory by virtue of their size may be older than they appear.

Blue Mountains woodlands are composed primarily of western juniper. During the sample period, stem-exclusion structure increased sharply by 67 percent from an average of 2.4 to 4.0 percent of the ERU. Connectivity of stem-exclusion structure also increased (appendix 2). We believe that expansion of western juniper cover and the associated stem-exclusion structure was the result of fire exclusion and grazing. Grazing minimized herbaceous competition and the possibility of surface fires, and fire exclusion enabled uninhibited expansion of juniper cover.

***Central Idaho Mountains ERU*—**Forests of the Central Idaho Mountains are comprised primarily of cold and moist PVTs (see fig. 70 and Hann and others 1997). Historical fire regimes were predominantly of mixed severity with infrequent (76 to 150 years) to very infrequent (151 to 300 years) fire return intervals (see fig. 71, A and B, and Hann and others 1997). Historical forest cover was dominated by upper montane and subalpine species such as Engelmann spruce, subalpine fir, lodgepole pine, grand fir, and Douglas-fir (table 29 and appendix 2). Our results suggest that fire suppression and exclusion were primary factors responsible for current forest composition and structure. Road densities are among the lowest of any forested ERU (see fig. 73 and Hann and others 1997), and wilderness and roadless area is greatest of any forested ERU. In our historical vegetation condition, we would have expected stand-initiation structures to represent a relatively large fraction of Central Idaho Mountains forest landscapes because mixed severity fires with infrequent fire return typically create a mosaic of underburned and regenerated patches of new forest. Area in stand-initiation structures declined during the sample period by 39 percent, from an average historical level of 9.7 percent of the ERU to 5.9 percent. We believe the observed decline occurred primarily as a result of effective fire prevention and suppression efforts and secondarily as a consequence of fire exclusion. Although timber harvest activities and road network development were evident, most of these activities were associated with dry and moist forest settings of lower and middle montane environments or were in areas with extensive lodgepole pine cover that had been attacked by bark beetles and salvage logged or regenerated. A large, intact, interior core area of the ERU comprised mainly of cool and cold upper montane and subalpine forests was mostly unroaded and had not been entered for timber harvest.

In our historical vegetation condition, old forests comprised 3.2 percent of the ERU area, or 4.4 percent of the total historical forest. Old-forest area in the current condition was essentially unchanged. Likewise, area with large trees, whether in old forest or associated with other forest structures, was unchanged (table 20). Area with medium and large trees increased significantly during the sample period (table 21). In the historical condition, 23.5 percent of the ERU area (32 percent of the forest) was occupied by forest structures comprised of medium and large trees. In the current condition, 25.8 percent of the ERU (35 percent of the forest) is occupied by forest structures comprised of medium and large trees.

Area in understory reinitiation structures increased significantly during the sample period to become the dominant structural component of Central Idaho Mountains forests in the current condition. We believe that the observed increase in understory reinitiation structure was the result of fire exclusion: areas regenerated by fire before our historical coverage have regrown. In the absence of fire, we predict a correlated decline in area and connectivity of early seral shrub and herb structures in forest potential vegetation settings.


A
lethal-frequent
lethal-infrequent
lethal-very Infrequent
lethal-extremely infrequent
mixed-very frequent
mixed-frequent
mixed-infrequent
mixed-very infrequent
nonlethal-very frequent
nonlethal-frequent
nonlethal-infrequent
rarely burns
state boundaries
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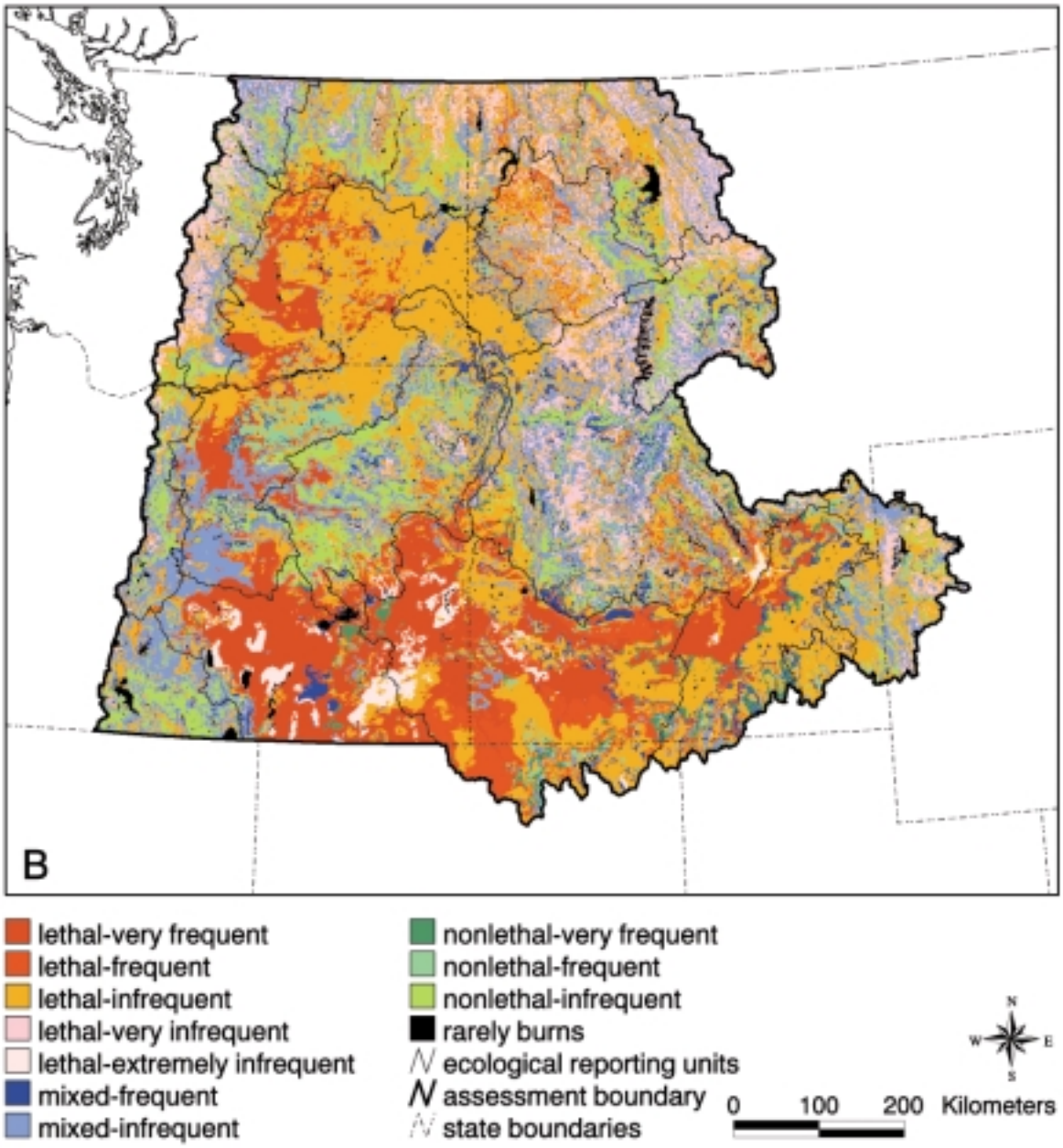

Figure 71—Broadscale (1-km^2 pixels) map of (A) historical and (B) current fire regimes within the interior Columbia River basin assessment boundary. See Hann and others (1997) for map development procedures. Lethal = stand-replacing fire that kills > 70 percent of the overstory tree basal area; nonlethal = fire that kills < 20 percent of the overstory tree basal area; mixed = fire that kills 20 to 70 percent of the overstory tree basal area; and rarely burns = fire seldom occurs. Very frequent = 0- to 25-year mean fire-return interval; frequent = 26- to 75-year mean fire-return interval; infrequent = 76- to 150-year mean fire-return interval; very infrequent = 151- to 300-year mean fire-return interval; and extremely infrequent = > 300-year mean fire-return interval.

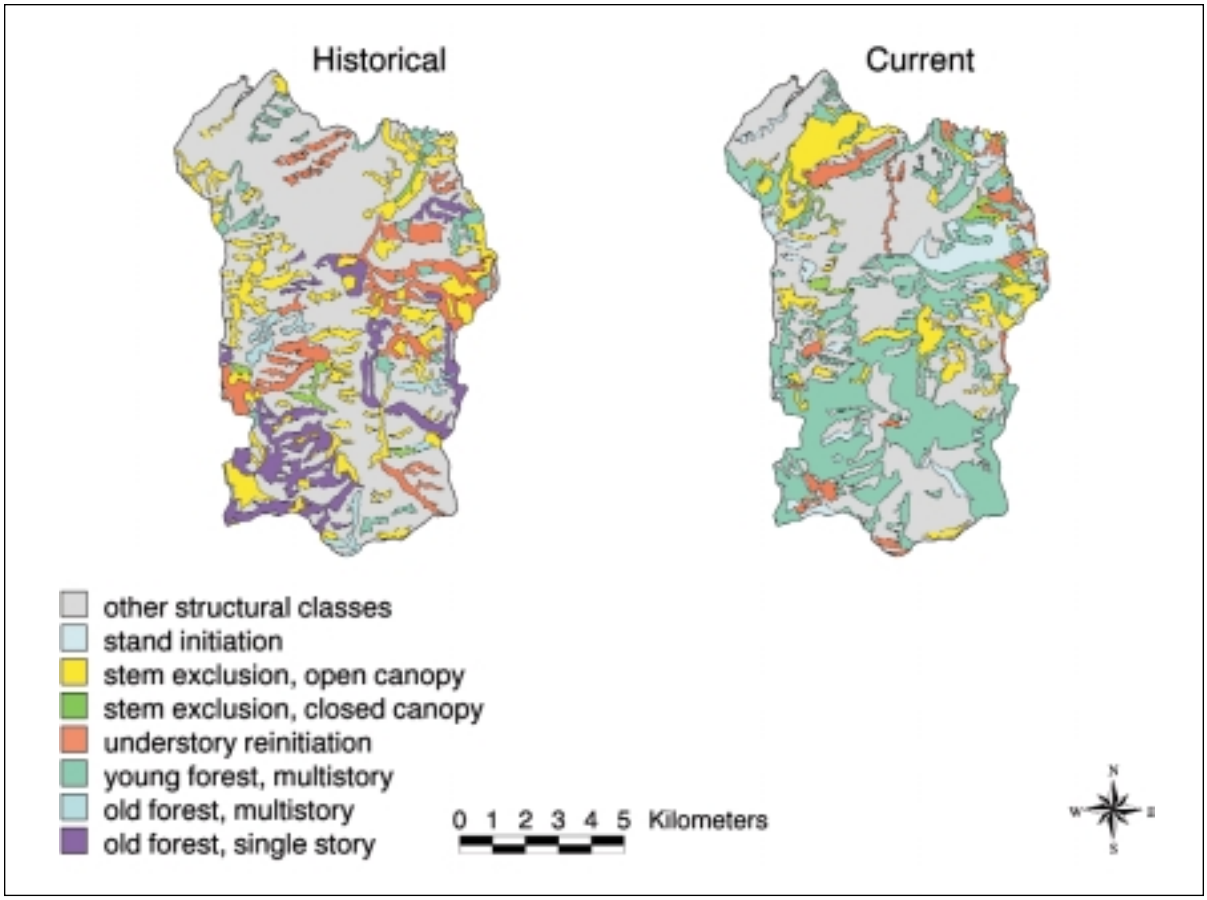

Figure 72—Historical and current maps of forest and woodland structural classes in subwatershed 21 in the Lower Grande Ronde subbasin of the Blue Mountains ERU.

Columbia Plateau ERU—Forests of the Columbia Plateau ERU are comprised of dry and moist potential vegetation types. Historical fire regimes were predominantly nonlethal with very frequent (0 to 25 years) fire return intervals (see fig. 70 and Hann and others 1997). The majority of historical forest cover was ponderosa pine and Douglas-fir (table 29 and appendix 2). Before European settlement, the Columbia Plateau contained the largest expanses of native grasslands in the whole of the Columbia River basin (see fig. 74 and Hann and others 1997). During the period of settlement, even to the current day, these grasslands and shrublands have been converted to dryland and irrigated agriculture and pasturelands (fig. 70). Presettlement herblands burned frequently, and fires often spread to lower and mid montane dry forests (Arno 1980). With herbland conversion to agriculture, dry and mesic forests of the Columbia Plateau became isolated from fires that had commonly originated in herbland and shrubland settings. Fire prevention and suppression efforts minimized the incidence of fires originating from within, especially adjacent to human settlements. In the absence of fires from once adjacent herblands, and in the context of aggressive fire suppression, forest area expanded by 11 percent, from an average of 26.1 to 29.1 percent of the ERU, and juniper woodlands expanded by 82 percent, from an average of 6.7 to 12.2 percent of the ERU. We expected to see significantly increased total tree crown cover in forest settings (table 22).

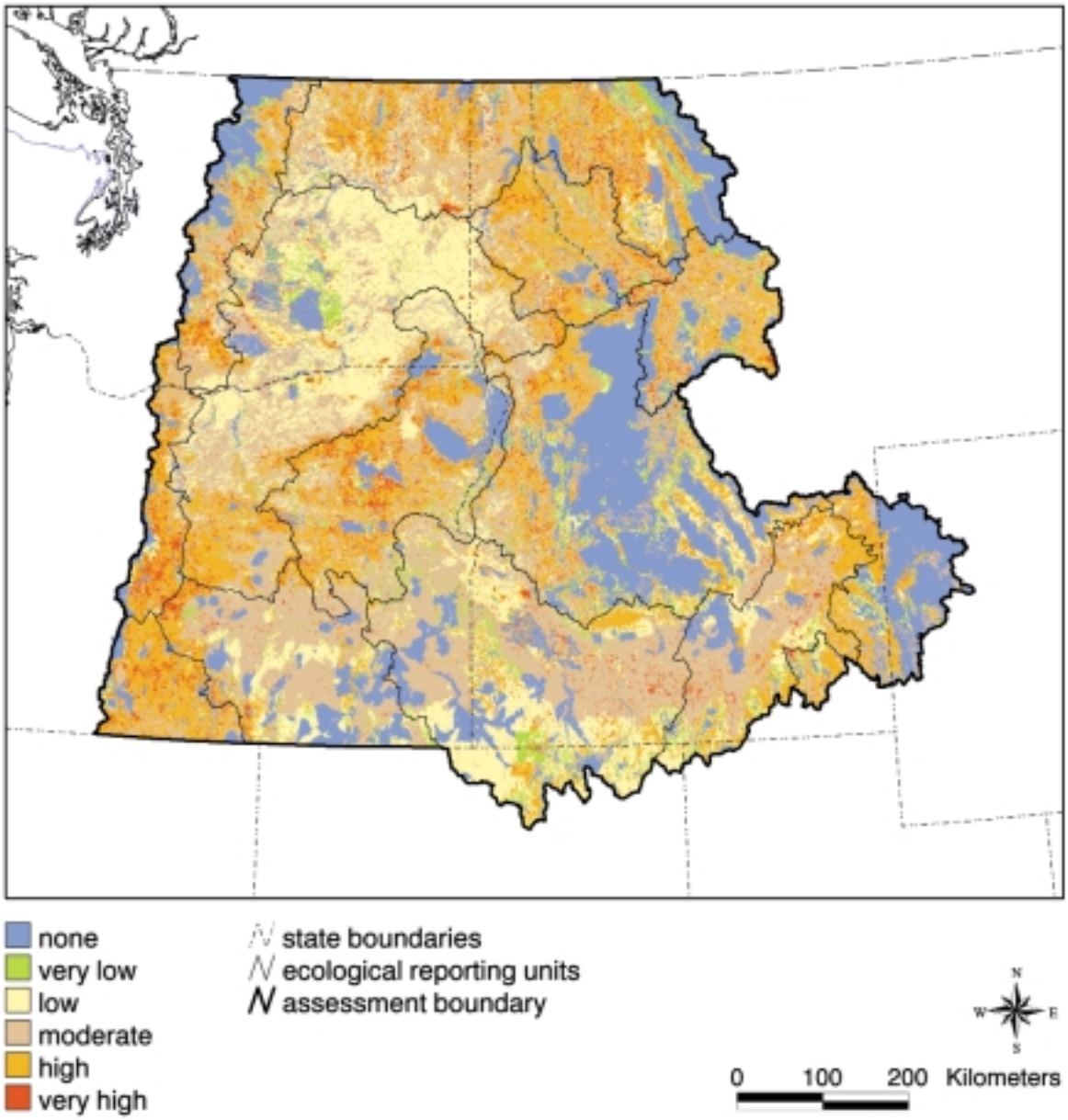

Figure 73—Broadscale (1-km^2 pixels) map of current predicted road density classes within the interior Columbia River basin assessment boundary. See Hann and others (1997) for map development procedures. None = 0 to 0.01 km/km^2; very low = 0.01 to 0.06 km/km^2; low = 0.06 to 0.43 km/km^2; moderate = 0.43 to 1.06 km/km^2; high = 1.06 to 2.92 km/km^2; and very high = > 2.92 km/km^2.

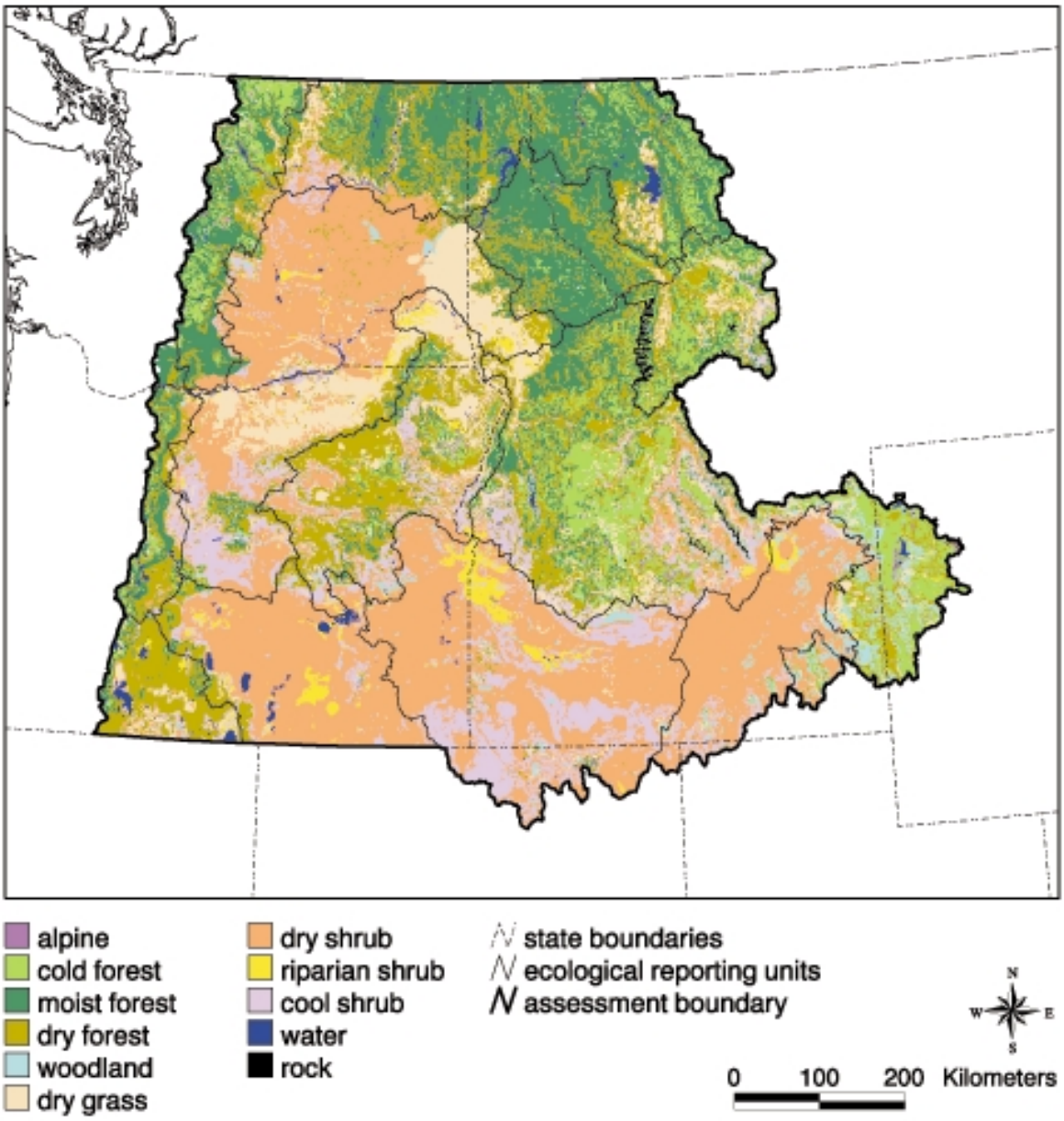

Figure 74—Broadscale (1-km^2 pixels) map of historical potential vegetation groups within the interior Columbia River basin assessment boundary. See Hann and others (1997) for map development procedures.

Evidence from these analyses suggests that agriculture, fire exclusion, timber harvest, and grazing each had an effect on existing forest structure. In the historical condition, we expected stand-initiation structures to occupy a minor fraction of Columbia Plateau forest landscapes because surface fire regimes continuously regenerated multicohort forests dominated by early seral species. Historical area in stand-initiation structures was 2.3 percent of the ERU and remained stable during the sample period. In our historical vegetation condition, old forests comprised 3.4 percent of the ERU, or 13 percent of the total forest. Selective harvests have diminished that area to a small remnant in the existing condition. Selective harvest of medium and large trees in a management context of fire control and grazing would promote development of more total crown cover (table 22), less grass-forb and shrub understory cover and greater conifer understory cover (table 25), increased vertical complexity of forest canopies (table 23), and increased cover of shade-tolerant understories (table 24). All but one of these changes were observed; grass-forb and shrub understory cover actually increased during the sample period. Transition analysis revealed that such increase was associated with expanding forest and woodland in former native herbland and shrubland areas (table 24 and appendix 2).

For the Columbia Plateau, we predicted that stem exclusion-open canopy structures were common in the historical condition because dry potential vegetation types are typically moisture limited, and surface fire regimes tend to maintain open stand conditions and dry site climate. Area in open canopy, stem-exclusion structures was 6.7 percent of the ERU in the historical condition and remained stable during the sample period. During the sample period, area in young multistory structures increased from 28 to 34 percent of the forest area (table 29 and appendix 2). Figure 75 provides an example of increased area of young multistory structure in a subwatershed of the Lower John Day subbasin. We were again surprised to find such an extensive area in young multistory forest structures in our historical coverage. As suggested for the Blue Mountains, we believe that it is likely that ongoing insect, pathogen, and fire disturbances exerted a greater mortality influence on overstory structure than we had anticipated, such that large tree structure was not dominant; that is, it did not exceed 24 percent crown cover. Large and medium trees are those most likely to be old and decadent or declining in vigor, and such trees are the most probable targets of tree-killing bark beetles that favor vigor-depressed hosts. Dry ponderosa pine forests often are afflicted with western dwarf mistletoe and S-group annosum root disease, pathogens of ponderosa pine of any age. Forests such as these are especially sensitive to dry growing seasons, winter desiccation injury, and protracted droughts. Pine bark beetles have ample opportunities to capitalize on hosts vigor-depressed from a variety of independent or interacting factors. It is also possible that some areas were affected by partial cutting before the period of our historical coverage, and we were not able to detect the logging entry, and some structures classified as young multistory by virtue of their size may be older than they appear.

Western juniper woodland cover in the Columbia Plateau nearly doubled in the interval between our historical and current vegetation conditions. Nearly all change in woodland structure was associated with stem-exclusion structures, which increased from an average of 5.9 to 10.9 percent of the ERU (fig. 75). Connectivity of woodland stem-exclusion structure also increased dramatically (appendix 2); mean patch size rose from 63.8 to 152.7 ha, representing a 239-percent rise for the period. In the absence of fire and under the influence of grazing, we expected increases in both the stem-exclusion and understory reinitiation structures (table 29).

Lower Clark Fork ERU—Forests of the Lower Clark Fork are comprised primarily of moist PVTs (see fig. 70 and Hann and others 1997). Historical fire regimes were predominantly lethal crown fires and of mixed severity with fire frequencies ranging broadly from very frequent (0 to 25 years) to extremely infrequent (> 300 years) (see fig. 71, A and B, and Hann and others 1997). Historical forest cover was dominated by grand fir, Douglas-fir, western hemlock, and western redcedar (table 29 and appendix 2). Our

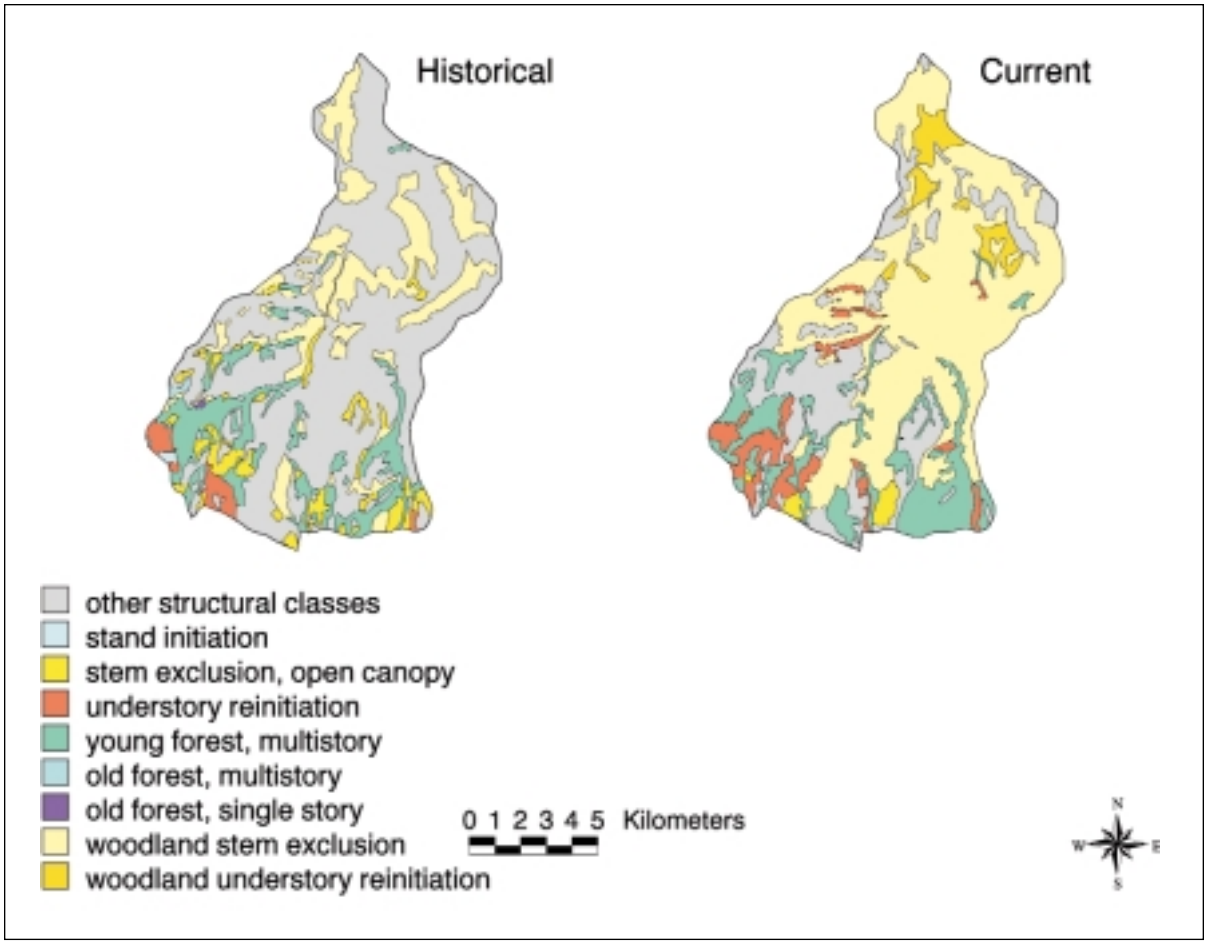

Figure 75—Historical and current maps of forest and woodland structural classes in subwatershed 2701 in the Lower John Day subbasin of the Columbia Plateau ERU.

results suggest that timber harvest, fire suppression, and fire exclusion were primary factors responsible for current forest composition and structure. Road densities are high throughout the ERU (see fig. 73 and Hann and others 1997), and there is scant roadless area.

From our historical vegetation condition, we expected stand-initiation structures to represent a large fraction of Lower Clark Fork forest landscapes, and indeed they did, because a sizable area was burned just before and after the start of the 20th century. In the historical condition, stand-initiation structures occupied 32.7 percent of the ERU area (35.7 percent of the forested area). Area in stand-initiation structures declined during the sample period by 71percent, plummeting to an average of 9.5 percent of the ERU in the current condition. We believe the observed decline occurred primarily as a result of effective fire prevention and suppression efforts. Figure 76 provides an example of substantially reduced area of stand-initiation structures in a subwatershed of the Upper Coeur d'Alene subbasin. Also noteworthy, among ERUs, area affected by regeneration harvesting increased most significantly in the Lower Clark Fork (table 27). While small staggered-setting clearcut and shelterwood harvest units were increasing in abundance, area of stand-initiation structure declined on nearly one-quarter of the land area of the ERU. These results clearly

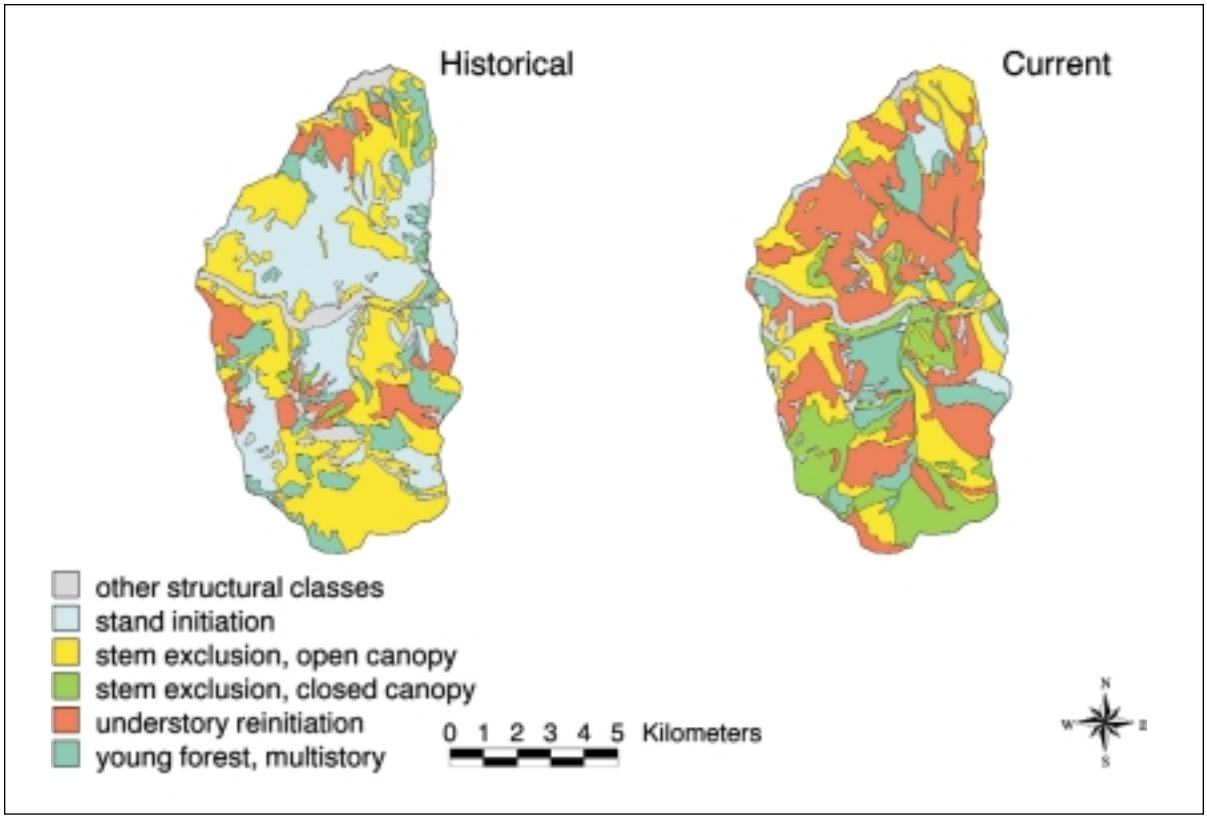

Figure 76—Historical and current maps of forest and woodland structural classes in subwatershed 1401 in the Upper Coeur d'Alene subbasin of the Lower Clark Fork ERU.

suggest that small, regularly sized and shaped clearcut harvest units are not an adequate substitute for larger scale disturbance events that leave coarse-grain patterns on affected landscapes.

In our historical vegetation condition, old forests comprised 2.4 percent of the ERU area, or 2.6 percent of the total historical forest. Area of old forest in the current condition was essentially unchanged (table 29 and appendix 2). Likewise, area with large trees, whether in old forest or associated with other forest structures, was unchanged (table 20). Area with medium and large trees increased significantly during the sample period (table 21); we believe the observed increase was associated with fire exclusion and subsequent succession and aging of forests. In the historical condition, 21.8 percent of the ERU area (23.8 percent of the forest) was occupied by forest structures comprised of medium and large trees. In the current condition, 36.8 percent of the ERU area (38.9 percent of the forest) was occupied by forest structures comprised of medium and large trees.

Area in understory reinitiation structures increased quite significantly during the sample period to become the dominant structural feature of Lower Clark Fork forests in the current condition. We believe, and transition analysis confirmed, that the observed increase in understory reinitiation structure was the result of fire exclusion: areas regenerated by fire before our historical coverage have regrown.

Table 27 shows that at the starting point of our historical vegetation coverage, nearly 22 percent of the ERU area had been influenced by selective harvest entry. In the current condition, area

affected by selective harvesting fell to 16.4 percent, but the change was not statistically significant. Such extensive selective harvesting in a management context of fire suppression would promote development of more total crown cover (table 22), less grass-forb and shrub understory cover and greater conifer understory cover (table 25), increased vertical complexity of forest canopies (table 23), and increased cover of shade-tolerant understories (table 24). All these changes were observed.

Northern Cascades ERU—Forests of the Northern Cascades are comprised primarily of moist and cool to cold PVTs (see fig. 70 and Hann and others 1997), with dry and mesic types represented on the eastern fringe. Historical fire regimes were predominantly of mixed severity with infrequent (76 to 150 years) to frequent (26 to 75 years) fire return intervals (see fig. 71, A and B, and Hann and others 1997). Surface fire regimes represented a relatively modest area where ponderosa pine was a major early seral species. Fire return intervals in areas with surface fire regimes were frequent (26 to 75 years) and very frequent (0 to 25 years).

Forests of the Northern Cascades are among the most varied in composition of all forests in the basin, with most east- and west-slope Cascade Range conifers represented. Historical forest cover was dominated by Douglas-fir, Engelmann spruce, subalpine fir, ponderosa pine, lodgepole pine, Pacific silver fir, western hemlock, and western redcedar (appendix 2 and table 29). Results from our analysis suggest that fire exclusion and suppression and timber harvest were primary factors responsible for current forest composition and structure.

Road densities are very low in upper montane and subalpine settings, increasing in density with decreasing elevation (see fig. 73 and Hann and others 1997). Wilderness and roadless areas are associated with upper montane and subalpine settings. Change in area of forest structures in the Northern Cascades was relatively minor in comparison with that observed in other forested ERUs. But change in connectivity of forest structures was among the most significant (appendix 2). We speculate that the observed reduction in grain of Northern Cascades forest landscapes was the result of excluding fire, an agent of relatively coarse grain pattern formation, and introducing comparatively fine-grained selection cutting and staggered setting regeneration harvests (Franklin and Forman 1987).

Relative to fire disturbances, forest landscapes of the Northern Cascades appear to be more synchronous today than they were in the historical condition (Ottmar and others, in prep.). Here and elsewhere in the basin, many environments that once supported mixed severity fire regimes today support lethal crown fire regimes. Most environments that once supported lethal crown fire regimes still support lethal regimes, but it is as yet unknown whether fire behavior attributes under a wildfire burn scenario are any longer comparable with those of the historical condition. In the Northern Cascades, fire-free intervals have lengthened dramatically in nearly all environmental settings. Thus, in a management context of active fire prevention and suppression, climate-driven fires predominate. Climate cycles ordinarily drive fire cycles, especially in areas dominated by mixed and lethal crown fire regimes. But, in the historical condition, depending on the condition of forests in any given landscape, the results of an extended dry climatic period and its associated fires may have been large areas of old forest, a variable patchwork of forest structural conditions, or large areas of young, early seral forest or shrubland. In the current condition, the likelihood of extensive stand replacement is high.

From our historical vegetation condition, we expected that stand-initiation structures would represent a relatively large fraction of Northern Cascades forest landscapes because mixed severity fires typically regenerate patches of new forest. Area in stand-initiation structures remained relatively constant during the sample period as a result of regeneration harvests, patch clearcutting, and removal cutting (table 27). In the historical vegetation condition, old forests comprised 10.1 percent of the ERU area, or 12.8 percent of the total forest area. Selective and regeneration harvests have diminished that area by one-half. Decline in area occupied by medium and large

trees associated with all forest structures also was significant (tables 20 and 21). In the historical condition, an average of 41.9 percent of the ERU (53 percent of the forest) was occupied by forest structures comprised of medium and large trees. In the current condition, 37.9 percent of the ERU (48.5 percent of the forest) is occupied by forest structures comprised of medium and large trees.

Oregon white oak woodland cover increased by 50 percent during the interval between our historical and current vegetation coverages, and total woodland area more than doubled, rising from 0.3 to 0.7 percent of the ERU. Nearly all change in area of woodland structure was associated with stem-exclusion structures, which increased from an average of 0.3 to 0.6 percent of the ERU. Connectivity of woodland stem-exclusion structure also increased; patch density rose from 1.0 to 1.7 patches per 10 000 ha, and mean patch size rose nearly threefold from 2.3 to 6.3 ha. In the absence of fire, and under the influence of grazing, we expected increases in both the stem-exclusion and understory reinitiation structures.

Northern Glaciated Mountains ERU— Forests of the Northern Glaciated Mountains are comprised primarily of moist and dry PVTs (see fig. 70, and Hann and others 1997), but cold types are present throughout and are especially dominant in the eastern portion of the ERU in the North, Middle, and South Fork Flathead River drainages. Historical fire regimes were predominantly of mixed severity in the eastern two-thirds of the ERU, with fire return intervals ranging from 0 to 300 years (see fig. 71, A and B, and Hann and others 1997). Surface fire regimes characterized the western third of the ERU, including the Okanogan Highlands, from the Okanogan River drainage east to the Kettle and Sanpoil River drainages in Washington State, and the Lower Flathead River area in northwestern Montana. Fire return intervals ranged from 0 to 150 years. Historical forest cover was dominated by species such as Douglas-fir, western larch, ponderosa pine, Engelmann spruce, subalpine fir, and lodgepole pine (table 29 and appendix 2). Our results suggest that fire exclusion and suppression and timber harvest were primary factors responsible for current forest composition and structure. Road densities are high throughout forests of the ERU (see fig. 73 and Hann and others 1997), and wilderness and roadless area of any consequence is present only in the Swan River drainage and in the North, Middle, and South Fork Flathead River drainages on the eastern edge of the ERU.

Given the historical vegetation condition, we expected stand-initiation structures to represent a relatively large fraction of Northern Glaciated Mountains forest landscapes because of the large area of mixed severity fire regimes. Area in stand-initiation structures declined during the sample period from an average historical level of 16.9 to 9.4 percent of the current ERU area. We believe the observed decline occurred primarily as a result of effective fire prevention and suppression efforts and fire exclusion. In our starting point historical coverage, stand-initiation structures occupied 21 percent of the forest area. In the current condition, stand-initiation structures occupied 12 percent of the forest area. Also noteworthy, area affected by regeneration harvests increased more than threefold from an average of 2.3 to 7.9 percent of the ERU (table 27). Small staggered-setting clearcut and shelterwood harvest units increased in abundance, and area of stand-initiation structures precipitously declined.

In our historical vegetation condition, old forests comprised 1.2 percent of the ERU, or 1.5 percent of the total historical forest. Area of old forest in the current condition was essentially unchanged. Likewise, area with large trees, whether in old forest or associated with other forest structures, was unchanged (table 20). Area with medium and large trees increased significantly during the sample period (table 21). In the historical condition, 22 percent of the ERU area (27 percent of the forest) was occupied by forest structures comprised of medium and large trees. In the current condition, 24.2 percent of the ERU (30 percent of the forest) was occupied by forest structures comprised of medium and large trees.

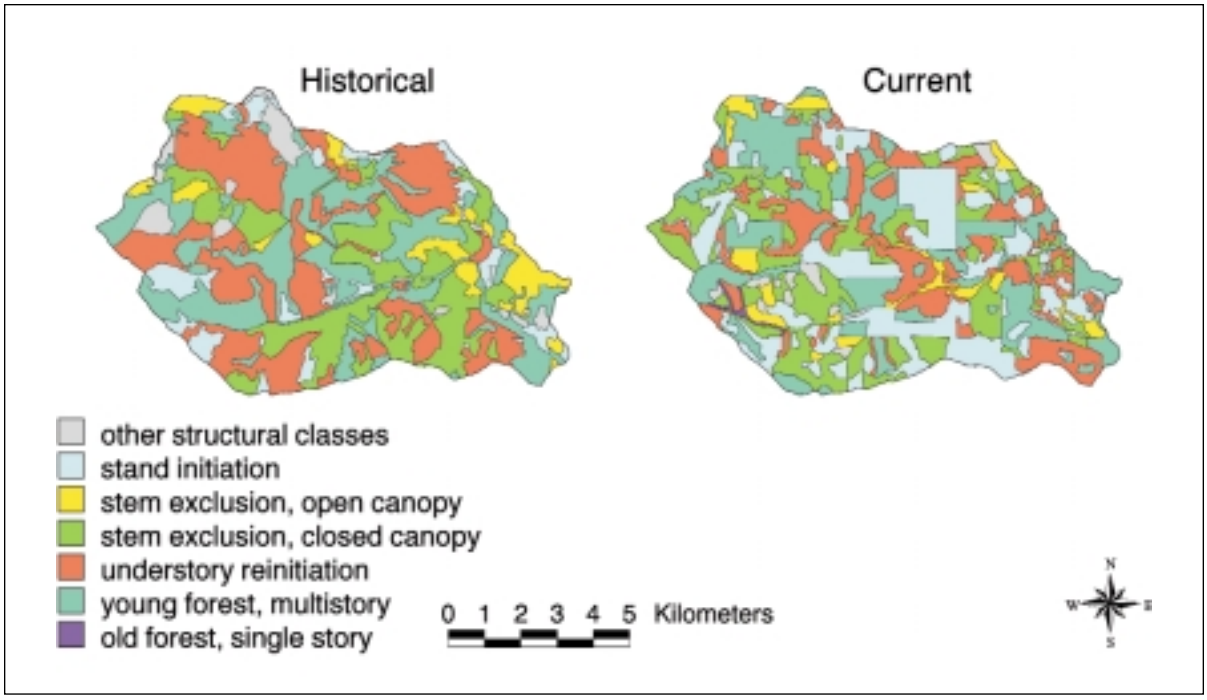

Figure 77—Historical and current maps of forest and woodland structural classes in subwatershed 09 in the Pend Oreille subbasin of the Northern Glaciated Mountains ERU.

Area in understory reinitiation structures increased significantly during the sample period to become the dominant structural feature of Northern Glaciated Mountains forests in the current condition. We believe that the observed increase in understory reinitiation structure is the result of fire exclusion and selective harvesting (table 27): areas regenerated by fire before the historical coverage have regrown, and partial cut areas have partially regenerated. Area in stem-exclusion closed canopy structures also increased significantly. In the current condition, 87 percent of forest structure is intermediate (stem-exclusion, understory reinitiation, or young multistory), 1 percent is old, and 12 percent is new forest. In appendix 2, we see that the connectivity of most major forest cover types and structural classes declined significantly. In most cases, patch density increased, and mean patch size declined. Our results suggest that these changes are characteristic of the combined effects of not only fire exclusion but also regeneration and selective harvesting at scales differing from natural disturbance patterns. Area and connectivity of most of the major early seral species declined (timber harvest), area of new forest structure declined, and area of intermediate forest structure increased (fire exclusion and timber harvest). Figure 77 provides an example of increased patch density and reduced patch size of forest structures in a subwatershed of the Pend Oreille subbasin.

***Northern Great Basin ERU*—**In the portion of the Northern Great Basin that we sampled, forests were comprised primarily of hardwoods, which occupy about 7 percent of the ERU land area. Forest structure is open because growing conditions are severely moisture limited. No changes in forest structure were noteworthy, but woodland structure did change significantly (table 29 and appendix 2). Woodlands in this ERU are comprised of western juniper, and they are also

severely moisture limited. In our historical coverage, most woodlands were characterized as stem-exclusion structure. Area in woodland stem-exclusion structure increased by 45 percent from an average of 15.3 to 22.2 percent of the ERU. We were surprised that we did not observe a significant reduction in patch density and a significant rise in mean patch size. In fact, connectivity of woodland structure did not change during the sample period.

Owyhee Uplands ERU—According to our sample, forests represent less than 1 percent of the ERU area. No changes in forest structure were significant or noteworthy, but woodland structure did change significantly (table 29 and appendix 2). Woodlands in this ERU are comprised of western juniper and are severely moisture limited. In our historical coverage, most woodlands were characterized as stem-exclusion structure. Area in woodland stem-exclusion structure increased 25 percent from an average of 5.2 to 6.5 percent of the ERU. Total area of juniper cover increased by 36 percent from a historical average of 5.5 to 7.5 percent of the ERU in the current condition. Most of the increase was from stem-exclusion structure. Patch density of stem-exclusion structure declined and mean patch size increased, as was expected. Our results suggest that under the influence of fire exclusion and grazing, most of the observed increase in woodland structure was associated with conversion of shrubland to woodland.

Snake Headwaters ERU—Forests of the Snake Headwaters are comprised primarily of cold and dry potential vegetation types (see fig. 70 and Hann and others 1997). Historical fire regimes were predominantly lethal crown fire with infrequent (76 to 150 years) to very infrequent (151 to 300 years) fire return intervals (see fig. 71, A and B, and Hann and others 1997). Forest cover was dominated by upper montane and subalpine species. Nearly two-thirds (63 percent) of historical forest cover consisted of subalpine fir, Engelmann spruce, lodgepole pine, and whitebark pine (table 29 and appendix 2). Montane environments were dominated by Douglas-fir and aspen. Our results suggest that fire exclusion and timber harvest were primary factors responsible for current forest composition and structure. Road densities are relatively low throughout much of the ERU (see fig. 73 and Hann and others 1997), and large wilderness and roadless areas are present in the Snake Headwaters, Gros Ventre, Lower Henry's, Grey's-Hobock, and Palisades subbasins.

In the historical condition, we would have expected stand-initiation structures to occupy a relatively small fraction of forest landscapes because fire return intervals were quite long and forest regeneration appears to be primarily event driven rather than continual. Area in stand-initiation structures remained unchanged (table 29), but connectivity of area increased (appendix 2). Area affected by regeneration harvests and small patch clearcutting increased from an average of 0 to 1.4 percent of the ERU (table 27). It was apparent that area affected by regeneration harvests increased during the sample period, and area with no visible logging declined from an average of 74.7 to 72.4 percent of the ERU (the forested proportion of the land area of the ERU); the change was not statistically significant at $P \leq 0.2$ (table 27). In our historical vegetation condition, old forests comprised 5.2 percent of the ERU area, or 7 percent of the total forest. Harvesting had diminished that area by 40 percent in the current condition (table 20).

For the Snake Headwaters, we predicted that stem exclusion-open canopy structures would be quite common in the historical vegetation coverage because both dry and cold PVTs of the area often are moisture limited. Area in open and closed canopy, stem-exclusion structures declined significantly during the sample period from an average of 19.1 to 15.3 percent and from 7.9 to 4.8 percent of the ERU, respectively. Results suggest that harvest of lodgepole pine and mountain pine beetle mortality were associated with the decline (tables 21, 22, and 25 and appendices 2 and 3). A management context of fire exclusion would have encouraged development of increased vertical complexity of forest canopies (table 23), greater conifer understory cover (table 25), less grass-forb and shrub understory cover, and increased cover of shade-tolerant understories (table 24). All these changes were observed.

During the sample period, area in young multistory structures increased from one-quarter to nearly one-third of the forest area (table 29). We were again surprised to find such an extensive area in young multistory forest structures in our historical coverage. We suggest that two of three aforementioned explanations apply: (1) ongoing insect and pathogen disturbances in the interval between fires exerted a greater influence on landscape structure than we had anticipated; and (2) structures classified as young multistory by virtue of their size are much older than they appear, especially in the cold upper montane and subalpine environments of this ERU.

Southern Cascades ERU—Forests of the Southern Cascades are comprised primarily of moist and dry potential vegetation types (see fig. 70 and Hann and others 1997), with cold types well represented on the western fringe adjacent to the crest of Cascade Range but accounting for less than one-third of the area. Historical fire regimes were predominantly nonlethal surface fire or of mixed severity with fire return intervals mostly ranging from 0 to 150 years (see fig. 71, A and B, and Hann and others 1997). Surface fire regimes represented a large area, especially where ponderosa pine was historically a major early seral species. Very frequent (0 to 25 years) fire return was common across more than half of the ERU in areas of surface and mixed severity fire.

As in the northern Cascades, forests of the southern Cascades are highly varied in composition, with many east- and west-slope Cascade Range conifers represented. Historical forest cover was dominated by mountain hemlock, ponderosa pine, lodgepole pine, grand fir, white fir, Douglas-fir, and a wide assortment of other less abundant species such as Shasta red fir, incense-cedar, sugar pine, western white pine, Engelmann spruce, and subalpine fir (table 29 and appendix 2). Our results suggest that timber harvest, fire suppression, and fire exclusion were primary factors responsible for current forest composition and structure. Road densities are very high throughout the ERU (see fig. 73 and Hann and others 1997). Wilderness and roadless areas are relatively small and are in subalpine and alpine environmental settings along the Cascade crest.

Change in area of forest structures was relatively minor in comparison with observed changes in other forested ERUs. Reduced connectivity of forest structures was quite significant (appendix 2). We speculate that the observed reduction in grain of Southern Cascades ERU forest landscapes was the result of several interacting factors, including extensive road network development (fig. 73 and Hann and others 1997), selection cutting (table 27), and fire exclusion (see fig. 71, A and B).

In the historical vegetation condition, we expected that stand-initiation structures would represent a relatively large fraction of Southern Cascades forest landscapes because mixed severity fires typically regenerate variable-sized patches of new forest. Despite fire suppression efforts, area in stand-initiation structures remained relatively constant during the sample period as a result of regeneration harvests, patch clearcutting, and removal or heavy selection cutting (table 27), but connectivity sharply declined (appendix 2). Patch density increased sharply by 357 percent from 6.8 to 24.3 patches per 10 000 ha, and mean patch size declined by 56 percent from 171.5 to 75.4 ha. Clearly, stand-replacement disturbances early in the 20th century occurred at a much larger scale than those witnessed today.

In our historical vegetation coverage, old forests comprised 2.3 percent of the ERU area, or 2.9 percent of the total forest area. Area of old single-story and old multistory forest structures more than doubled during the sampling period (appendix 2), but area with remnant large trees associated with structures other than old forest (table 20) declined by 42 percent from an average of 5.2 to 3.0 percent of the ERU (ns). Area occupied by medium and large trees associated with all forest structures increased by 10 percent during the sample period (table 21). In the historical condition, 40.3 percent of the ERU area (50.1 percent of the forest area) was occupied by structures with medium or large trees. In the current condition, 44.3 percent of the ERU (50.2 percent of the forest) is occupied by forest structures comprised of medium or large trees. But average area in the forest physiognomic type rose by 10 percent from an average of 80.5 to 88.3 percent of the ERU, mainly as a result of regrowth of large

areas clearcut harvested before our historical vegetation coverage. We speculate that this area likely was dominated by patches with large ponderosa pine trees and old single-story structures.

Considering the dominant cover types and PVTs displayed in this ERU, we were surprised to see the relatively minor area in stem-exclusion closed canopy structures in the historical vegetation coverage. With regrowth of clearcut areas apparent in the historical vegetation coverage, we expected to see greater increase in area of this structure. About 20 percent of the ERU is currently comprised of the lodgepole pine cover type; a comparable portion was present in the historical starting point vegetation coverage (appendix 2). Much of the area of the lodgepole pine cover type resides on deep pumice flats where cold air ponding and early or late hard frosts are a common occurrence. In these locations, lodgepole pine is often described as an edaphic "climax" dominant. We expected to observe a considerable area of closed canopy stem-exclusion structure in these locations, but did not. We suspect that a rather simple explanation may account for the apparent absence of this structure in our historical coverage: we know that large landscape-scale mountain pine beetle outbreaks are responsible for coarse- and medium-grain pattern changes in lodgepole forests, but fine-grain, patch-scale mountain pine beetle disturbances may be more common than we suspected and may sum to highly significant change in landscape patterns. We, and others, perhaps have simplified our understanding of the relation between lodgepole pine forests, mountain pine beetles, and regenerative fires. Indeed, we observed that 46 percent of the ERU (57 percent of the forest) was comprised of young multistory structures in the historical coverage, and a comparable amount was present in the current condition. Young multistory structure is the structure we expected in great abundance where fine-grain disturbances are the norm and overstory dominance of large trees is seldom achieved.

Nearly all change in woodland was associated with stem-exclusion structures that increased in area from 0 to 0.4 percent of the ERU. Connectivity of woodland stem-exclusion structures also increased. In the absence of fire, and under the influence of domestic livestock grazing, we expected increases in both the woodland stem-exclusion and understory reinitiation structures.

Table 27 shows that at the start of our historical vegetation coverage, 9.2 percent of the ERU area had been influenced by selective harvest entry. In the current condition, area affected by selective harvesting rose to an average of 23.2 percent of the ERU. Such extensive selective harvesting in a management context of fire prevention and suppression promotes development of more total tree crown cover (table 22), increased vertical complexity of forest canopies (table 23), and increased cover of shade-tolerant understories (table 24). All these changes were observed.

Upper Clark Fork ERU—Forests of the Upper Clark Fork are comprised primarily of cold and dry PVTs (see fig. 70 and Hann and others 1997). Historical fire regimes were predominantly nonlethal surface fire or of mixed severity with fire return intervals typically ranging from 0 to 150 years (see fig. 71, A and B, and Hann and others 1997). Surface fire regimes represented a large area, especially where ponderosa pine or Douglas-fir historically were major early-seral species. Very frequent (0 to 25 years) and frequent (26 to 75 years) fire return was common over more than half of the ERU in areas prone to surface and mixed severity fire.

Historical forest cover was dominated by species such as Douglas-fir, lodgepole pine, Engelmann spruce, subalpine fir, ponderosa pine, whitebark pine, subalpine larch, and western larch (table 29 and appendix 2). Our results suggest that fire exclusion and suppression and timber harvest were primary factors responsible for current forest composition and structure. Road densities are moderately high throughout montane forests of the ERU (see fig. 73 and Hann and others 1997), and wilderness or roadless areas are small and in subalpine and alpine environmental settings.

In the historical vegetation condition, we expected stand-initiation structures to represent a relatively large fraction of Upper Clark Fork forest landscapes because of the large area of mixed severity fire regimes with infrequent fire return intervals. Area in stand-initiation structures

declined during the sample period by 30 percent from a historical level of 15.9 to 11.1 percent of the ERU in the current condition. Evidence suggests that the observed decline occurred primarily as a result of fire suppression and fire exclusion. In our historical coverage, stand-initiation structures occupied 18 percent of the forest area. In the current condition, stand-initiation structures occupied 12.9 percent of the forest area. Also noteworthy, area affected by regeneration harvesting increased significantly from an average of 5.5 to 11.6 percent of the ERU (table 27). Small, staggered-setting clearcut and shelterwood harvest units increased in abundance, and area of stand-initiation structures declined.

In the historical condition, old forests comprised 0.8 percent of the ERU, or 0.9 percent of the total historical forest. Area of old forests in the current condition was essentially unchanged. Likewise, area with large trees, whether in old forest or associated with other forest structures, was unchanged (table 20). Area with medium and large trees declined slightly during the sample period (table 21), but the change was not significant. In the historical condition, 19.7 percent of the ERU (22.6 percent of the forest) was occupied by forest structures comprised of medium and large trees. In the current condition, 17.2 percent of the ERU (20 percent of the forest) was occupied by forest structures comprised of medium and large trees.

Area in stem-exclusion closed canopy structures increased significantly during the sample period to become the codominant structural feature of Upper Clark Fork forests in the current condition. Our results suggest that the observed increase in stem-exclusion closed canopy structures is the result of fire exclusion and selective harvesting (table 27): areas regenerated by fire before our historical coverage have regrown. In the current condition, 86 percent of forest structure is intermediate (stem exclusion, understory reinitiation, or young multistory), 1 percent is old, and 13 percent is new forest. In appendix 2, we observe that the connectivity of most major forest cover types and structural classes declined significantly. In most cases, patch density increased, and average patch size declined. These changes are characteristic of the combined effects of fire exclusion and regeneration and selective harvesting. Area and connectivity of major early seral species cover declined (timber harvest), area of new forest structure declined, and area of intermediate forest structure increased (fire exclusion and timber harvest).

Upper Klamath ERU—Forests of the Upper Klamath ERU are comprised primarily of dry and mesic PVTs (see fig. 70 and Hann and others 1997). Historical fire regimes were predominantly nonlethal surface fire with frequent (26 to 75 years) to very frequent (0 to 25 years) fire return intervals (see fig. 71, A and B, and Hann and others 1997). More than one-half of historical forest cover was ponderosa pine (table 29 and appendix 2). Results from our analysis suggest that timber harvest, fire exclusion, and grazing each had a pronounced effect on current forest composition and structure.

In the historical condition, we expected stand-initiation structures to occupy only a minor fraction of Upper Klamath forest landscapes because surface fire regimes with frequent fire return typically regenerate forests continually via individual tree and small group killing. Area in stand-initiation structures increased from a historical level of 1.9 to 3.6 percent of the ERU (ns) as a result of regeneration and selective harvests or removal cutting (table 27) that occurred during the sample period. In the historical condition, old forests comprised 11.7 percent of the ERU, or 23.2 percent of the total forest area. In the current condition, old forests comprised 10.3 percent of the ERU, or 21.7 percent of the total forest area. Selective harvests have diminished that area significantly (appendix 2). Decline in area occupied by medium and large trees was perhaps the single greatest change occurring to all forest structures in the Upper Klamath (tables 20 and 21). In the historical condition, 43.3 percent of the ERU (86 percent of the forest) was occupied by forest structures comprised of medium and large trees. In the current condition, 27.4 percent of the ERU (58 percent of the forest) was occupied by forest structures with medium and large trees. Selection cutting of medium and large trees in a management context of fire control and extensive cattle grazing would have promoted development of more total crown cover (table 22), less

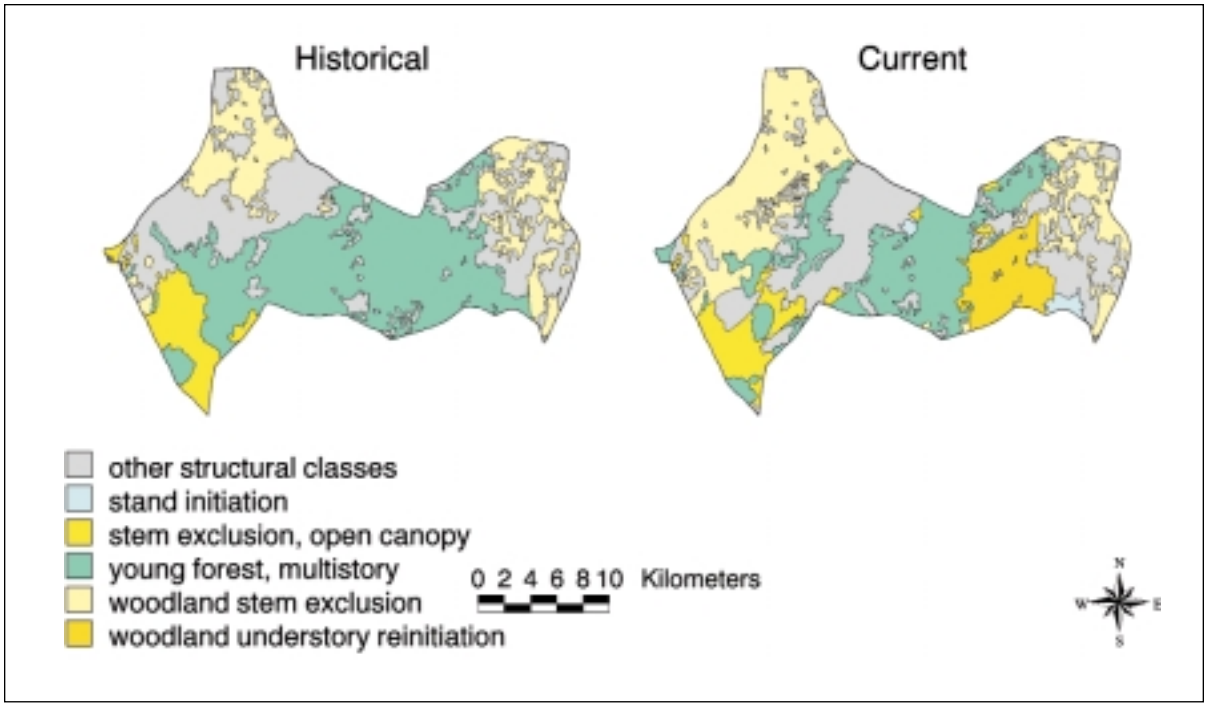

Figure 78—Historical and current maps of forest and woodland structural classes in subwatershed 0903 in the Lost subbasin of the Upper Klamath ERU.

grass-forb and shrub understory cover and greater conifer understory cover (table 25), increased vertical complexity of forest canopies (table 23), and increased cover of shade-tolerant understories (table 24). None of these changes was observed. In addition, extensive grazing would have minimized flashy fuel cover (Agee 1994), increasing opportunities for conifer understory development via reduced competition and reducing the likelihood of surface fires from natural or human-caused ignitions. Our findings suggest that for the period of our sample, the primary management influence in the Upper Klamath ERU was extensive and heavy timber harvest.

Area in young multistory structures declined for similar reasons (fig. 78). Repeated heavy partial cutting reduced forest crown cover (table 22), canopy layering (table 23), and conifer understory development (tables 24 and 25), thereby depleting area of young multistory structure (table 29).

Upper Klamath woodlands are composed chiefly of western juniper. During the sample period, area of stem-exclusion and understory reinitiation structures increased sharply (appendix 2 and fig. 78). We believe that expansion of the western juniper cover type and its associated stem-exclusion structure was the result of fire exclusion and grazing. Grazing minimized herbaceous competition and the possibility of surface fires, and fire exclusion enabled uninhibited expansion of juniper cover.

Upper Snake ERU—According to our sample, forests comprise about 3 percent of the ERU area. No changes in forest structures were particularly noteworthy, but two changes were statistically significant: area in stand-initiation structures declined, and area in stem-exclusion open canopy structures increased by a compensating amount. We speculate that fire exclusion was primarily responsible for the shift (see also tables 22, 23, 25, and 27).

Woodland structure also changed significantly (table 29 and appendix 2). Woodlands in this ERU are juniper and mixed pinyon and juniper, and they are severely moisture limited. In our historical coverage, most woodlands were characterized

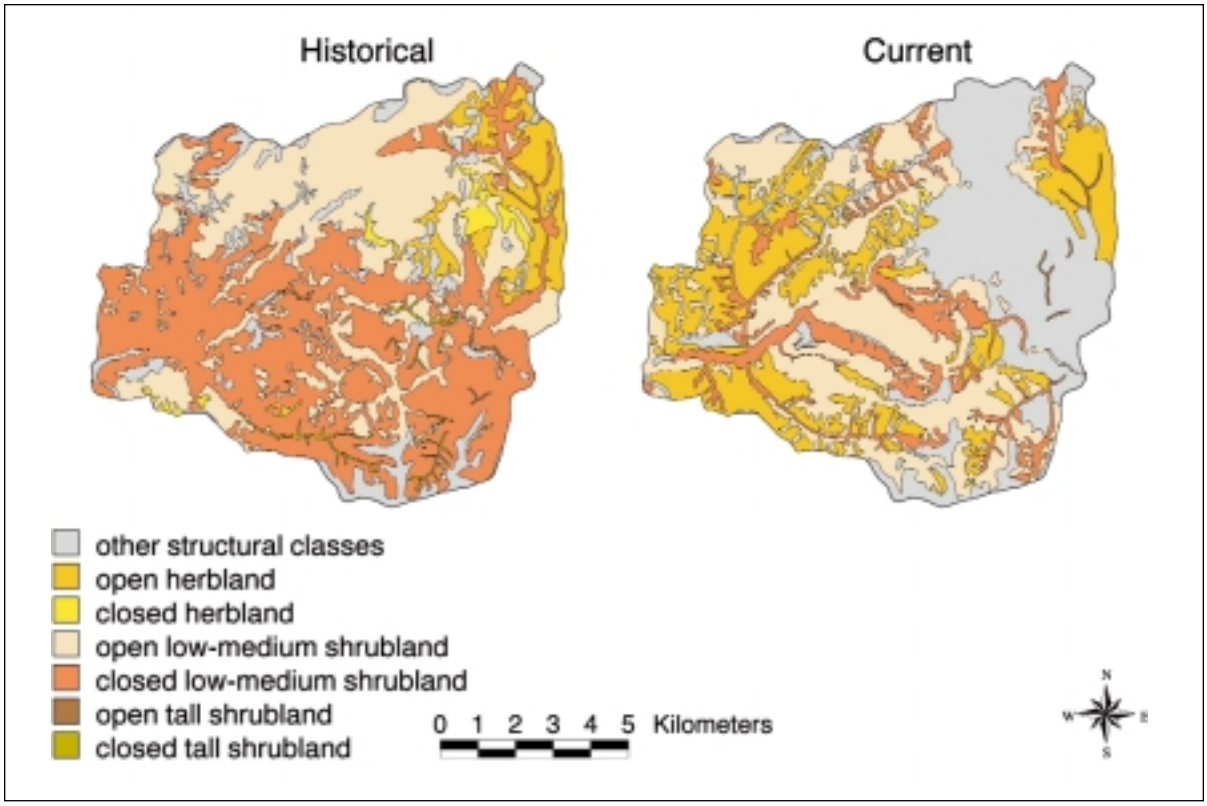

Figure 79—Historical and current maps of shrubland and herbland structural classes in subwatershed 1101 in the Lower John Day subbasin of the Columbia Plateau ERU.

as understory reinitiation structure. Area in woodland understory reinitiation structures declined, and area in stem-exclusion structures increased by a compensating amount. We speculate that this minor change in structure may have been associated with ongoing insect disturbance (table 25).

Shrubland and herbland structure—Area of open or closed shrub structure declined in every ERU where the shrubland physiognomic type comprised more than 0.5 percent of the area. The most significant loss of shrub structure occurring in the basin was the loss of open low-medium structures (primarily sagebrushes, rabbitbrush, and bitterbrush). Significant reductions in open low-medium shrub structures were noted in the Blue Mountains, Columbia Plateau, Northern Great Basin, Owyhee Uplands, and Snake Headwaters ERUs (table 29). Significant reduction in closed low-medium shrub structure was observed in the Columbia Plateau ERU. Figure 79 provides an excellent illustration of increased open herbland structure and reduced open and closed low-medium shrub structure in a subwatershed of the Lower John Day subbasin in the Columbia Plateau ERU. In general, the most significant losses to shrublands were associated with forest or woodland expansion as observed in the Blue Mountains and Northern Great Basin ERUs, cropland expansion as observed in the Northern Great Basin ERU, and conversion to seminative or nonnative herbland as observed in the Owyhee Uplands or Snake Headwaters ERUs.

Decline in shrubland area was the most significant change we observed during the sample period in the whole of the midscale assessment. Change was most conspicuous in ERUs where shrublands were a dominant physiognomic condition, such as in the Blue Mountains,

Columbia Plateau, Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs (table 29 and appendix 2). In the Blue Mountains, shrublands occupied 14.1 percent of the area in the historical condition. Shrubland area declined by 24 percent to 10.7 percent of the ERU, and most of the loss was to open low-medium structures. In the Columbia Plateau, shrublands occupied 32.2 percent of the area in the historical condition. Shrubland area declined by 27 percent to 23.4 percent of the ERU, and most of the loss was to open and closed canopy low-medium shrub structures. In the Northern Great Basin, shrublands occupied 72.8 percent of the area in the historical condition. Shrubland area declined by 21 percent to 57.6 percent of the ERU, and virtually all the loss was to open low-medium structures. In the Owyhee Uplands, shrublands occupied 88.8 percent of the area in the historical condition. Shrubland area declined during the sample period by 9 percent to 81.0 percent of the ERU, and most of the loss was to open low-medium structures. Finally, in the Upper Snake, shrublands occupied 73.8 percent of the area in the historical condition. Shrubland area declined by 7 percent to 68.5 percent of the ERU (ns), and most of the loss was to open and closed canopy low-medium structures. It is apparent that shrublands as a physiognomic condition, and that open low-medium shrub structures in particular, have been significantly diminished across the entire basin. We speculate that such a dramatic and expansive change must have produced equally significant and deleterious consequences for terrestrial species that rely on the presence of vast unbroken shrubland areas.

In general, open herbland area increased in most ERUs where significant reduction in open low-medium shrub structure occurred. We speculate that active range management activities to improve domestic livestock forage production were responsible for much of the noted expansion of open herbland area.

Landscape Patterns

The size and scale of ERUs as a pooling stratum preclude their use for project-level planning, but they are quite useful in providing context of individual watersheds and displaying significant province-scale change in vegetation patterns. When conditions of any watershed are examined, it is essential to understand the importance of various changes relative to the broader picture, not only the type but also the degree of change. Information of the sort we have provided answers questions on the rarity or uniqueness of any given patch type within a subwatershed or larger domain, currently and historically. And it enables one to gauge how representative current landscape patterns are compared with recent historical conditions. Additionally, when determining landscape changes, it is often difficult to understand the marriage of management and environmental causes behind observed changes. Comparative study of change in highly similar and differing ERUs, given their management histories, biophysical environment composition, climatic conditions, and disturbance regimes, enables us to better understand the relative contributions of each factor to the observed changes. These observations aid the understanding of the past and help to interpret or predict alternative management and climate futures. An even richer contribution to our understanding is the comparative study of landscape change at multiple scales, including pooling strata as large as ERUs and using smaller subregional strata and those in between. Such multiscale analyses provide insight to the magnitude and effects of changes at several relevant scales and contexts.

We conducted our landscape pattern analyses by using cover type-structural class couplets as the patch type because this combination is most intuitive for understanding simultaneous changes in patterns of structural and compositional attributes and terrestrial habitats. We first discuss change occurring across all ERUs for a given subset of metrics, and then we discuss changes across metrics by ERU.

Richness, diversity, and evenness— Patch richness (PR), SHDI, and the inverse of Simpson's λ (N2) provide different views of the diversity of cover-structure patch types across any landscape. Richness simply tallies the number of different patch types present without regard for their relative abundance; a patch type represented by a single patch counts as much as another patch type comprising 95 percent of the subwatershed area. The SHDI and N2 incorporate abundance into the measurement of diversity, but N2 responds to abundance changes in the most dominant patch types. Relative patch richness (RPR) rescales PR as a percentage of the total cover-structure patch types present in the basin (there were 192 reasonable cover-structure patch types). The SHDI (or its transformed equivalent N1) is intermediate in responsiveness between RPR and N2. In general, for the three measures of richness and diversity (RPR and PR, SHDI and N1, and N2), all ERUs displayed a positive mean difference with only two notable exceptions (table 19): the Lower Clark Fork and Upper Klamath ERUs exhibited minor declines in PR. We attributed these declines to an extended history of widespread timber harvest activity. Five of thirteen ERUs (the Central Idaho Mountains, Northern Cascades, Northern Glaciated Mountains, Southern Cascades, and Upper Clark Fork) displayed significant change in PR, generally on the order of a 15- to 30-percent increase. Eight of thirteen ERUs displayed significantly increased dominance and diversity (N2), thereby indicating that patch type numbers were not only increasing but also that new patch types were occupying significant landscape area. Ecological reporting units displaying an increase were the Lower Clark Fork, Northern Cascades, Northern Glaciated Mountains, Northern Great Basin, Owyhee Uplands, Snake Headwaters, Southern Cascades, and Upper Klamath.

Evenness measures are attempts to assess how equitably area is distributed among a given number of patch types. Both evenness measures (MSIEI and R21) index relative change in the distribution of "abundance," or in this case area, among patch types. Many ERUs displayed increased diversity, richness, and dominance during the sample period for the diversity measures we used. That typically results in a modest increase in the evenness measures used, if any change in evenness occurs at all. Our results confirmed this relation; the MSIEI and R21 increased significantly in six of eight ERUs displaying significantly increased diversity and dominance. The Upper Clark Fork and the Central Idaho Mountains were the only two ERUs to decline in evenness; the Upper Clark Fork declined significantly in both evenness measures. In the Central Idaho Mountains, few cover type changes were significant, but the distribution of area in forest structures became increasingly uneven. Area in stand-initiation structures declined from 9.7 to 5.9 percent of the ERU, and area in understory reinitiation structures increased from an average of 16 to 21.4 percent of the ERU. A similar pattern of change was evident in the Upper Clark Fork ERU; few cover type changes were evident, but distribution of area in stand initiation, closed canopy stem-exclusion, and young multistory forest structures became increasingly uneven (appendix 2).

Landscape metrics (table 19) computed in FRAGSTATS (McGarigal and Marks 1995) were averaged across sampled subwatersheds; for example, the value of CONTAG_c computed for the Northern Cascades ERU was derived by averaging all CONTAG values of individual subwatersheds in that ERU in the current condition. Hence, values for all metrics in the historical and current condition reflect the average per subwatershed. Some questions come to mind: What is the total richness and diversity of patch types of each ERU? and Have those values changed during the sample period? Heltshe and Forrester (1983) describe a "jackknife" estimator for richness that attempts to estimate total richness for a geographic area of interest. We applied this technique and a related jackknife estimator for N2 (Burnham and Overton 1979) to the historical and current patch type data for each ERU to estimate difference in richness and dominance for each ERU (table 30). The jackknife technique results in estimates of the total and the standard error. We used these statistics in simple two-way t-tests to test for significant change in richness or dominance across each

Table 30—"Jackknife" estimates of total patch-type richness and dominance (N2) for 13 ecological reporting units in the midscale assessment of the interior Columbia River basin where patch types were cover type-structural class doublets

Ecological reporting unit	Sampled watersheds	Richness		Dominance (N2)	
		Historical (s.e.)[a]	Current (s.e.)[a]	Historical (s.e.)[b]	Current (s.e.)[bc]
	Number				
Blue Mountains	44	114 (6.0)	123 (4.3)	23 (3.5)	20 (2.4)
Central Idaho Mountains	43	142 (6.4)	135 (5.7)	32 (2.9)	29 (2.7)
Columbia Plateau	38	121 (7.7)	119 (5.5)	10 (1.7)	11 (1.7)
Lower Clark Fork	5	88 (9.5)	73 (2.9)	19 (1.6)	17 (1.8)
Northern Cascade Mountains	47	135 (5.1)	133 (3.8)	36 (4.5)	36 (3.8)
Northern Glaciated Mountains	41	127 (5.1)	136 (5.4)	25 (2.4)	26 (2.7)
Northern Great Basin	4	22 (2.6)	29 (3.6)	4 (0.4)	5 (0.6)
Owyhee Uplands	22	40 (6.0)	41 (4.1)	1 (0.2)	2 (0.3)*
Snake Headwaters	15	83 (5.4)	92 (5.9)	30 (3.2)	26 (3.1)
Southern Cascades	16	69 (5.7)	80 (8.1)	15 (1.3)	15 (2.6)
Upper Clark Fork	32	113 (5.8)	120 (4.9)	25 (1.9)	23 (2.2)
Upper Klamath	13	107 (7.0)	100 (5.7)	13 (3.9)	16 (3.0)
Upper Snake	15	67 (8.3)	71 (6.5)	3 (0.4)	3 (0.9)

[a] Estimates of total richness and standard error (s.e.) were computed by using the methods of Heltshe and Forrester (1983). Estimates for total richness were rounded to the nearest integer.

[b] Estimates of total dominance (N2) and its standard error were computed by using the methods of Burnham and Overton (1979). Estimates for total dominance were rounded to the nearest integer.

[c] * indicates significant difference at P≤0.2.

ERU. All changes but one were insignificant at the ERU scale. Eight ERUs displayed nonsignificant increase in richness.

Jackknife estimates of richness are very sensitive to sample size and coverage. It is best in this instance not to make comparisons among ERUs, but comparisons between current and historical values are appropriate. Jackknife estimates for N2 are not restricted in this way. The N2 values across ERUs range from a low of 1 in the Owyhee Uplands to 36 in the Northern Cascades. We expect forest-dominated ERUs to display much larger values of total N2 than range-dominated ERUs because of the former's greater PR and diversity.

Contagion and interspersion—Contagion and IJI metrics were designed to quantify the extent to which patches or pixels of differing types intermix with one another. The IJI considers length of edge between contrasting patch types, and CONTAG estimates patch-type dispersion and interspersion for data in raster format. Both metrics are rescaled as a percentage of the maximum possible value, given the total number of patch types, and range in value from 0 to 100. As mean patch size increases, total edge length tends to decrease. We then expect that mean differences values for IJI and CONTAG will differ in sign, although this is not always true.

Seven of thirteen ERUs displayed significant declines in CONTAG, and all significant mean differences values were negative (table 19). Ecological reporting units displaying a significant decline were the Lower Clark Fork, Northern Cascades, Northern Glaciated Mountains, Northern Great Basin, Owyhee Uplands, Snake Headwaters, and Southern Cascades. A negative mean difference value of CONTAG indicated that across a given ERU, cover-structure patches became smaller during the sample period and more dispersed. Three of six ERUs with nonsignificant mean difference values of CONTAG

also exhibited a negative sign. These results point to a systematic basinwide decrease in contagion or connectivity of cover-structure patch types. With the exception of the Northern Great Basin and Owyhee Uplands ERUs, the magnitude of decrease was small relative to initial average historical values.

Only 4 of 13 ERUs displayed significant mean difference values for IJI; two were positive and two were negative (table 19). The Owyhee Uplands and Upper Snake ERUs were noteworthy because the magnitude of mean difference values for these two ERUs was especially large. Unlike CONTAG, there was no consistent pattern across ERUs for this metric, and most changes were small. We concluded that interspersion changes as measured by this metric were minimal at this reporting scale, and that changes in interspersion and patch type juxtaposition may be better observed at smaller scales where variability of biophysical environments is more readily controlled. For example, IJI values of subwatersheds pooled to subbasins indicated highly significant mean differences.

Edge contrast—The AWMECI uses a set of user-defined values ranging from 0 to 1 to represent relative edge contrast (table 18) between patch types, weighted by area, to evaluate change in edge contrast of a landscape or sample of landscapes. We based edge contrast on physiognomic and structural conditions in deference to edge-sensitive and -dependent terrestrial species, and their typically greater sensitivity to structural differences of edges. An increase in area-weighted mean edge contrast was indicated as the percentage of the total edge that was the equivalent of maximum contrast edge. The greater the difference in structure or physiognomic condition (for example, an old single-story forest patch adjacent to open herbland), the greater the edge contrast weight. Significant increase in AWMECI for a given landscape or sample of landscapes indicated that greater contrast in structural and physiognomic condition was occurring at patch edges. Six of thirteen ERUs displayed such a significant increase. Most increases were relatively modest except in the Lower Clark Fork ERU, where increase in maximum contrast edge averaged 5.1 percent of the total edge (table 19).

Pattern changes among ERUs—The Blue Mountains and Columbia Plateau ERUs displayed no significant change for any landscape metric. The sign of insignificant change was generally consistent with change occurring in other ERUs except as noted earlier for the contagion and interspersion indices. When we ranked the mean difference value for PR, SHDI, and N2 and then averaged the three ranking values, the Blue Mountains was 10th in overall change and the Columbia Plateau ERU was 12th. The jackknife index value of total richness increased in both ERUs, but insignificantly.

In the Central Idaho Mountains, significant changes in richness and SHDI were consistent with declining evenness as measured by R21. More patch types appeared on the landscape, yet the number of dominant types did not increase significantly. The Central Idaho Mountains ERU ranked seventh among ERUs in overall change in diversity and richness. Contagion and interspersion did not change significantly, but edge contrast rose significantly, thereby indicating increasing juxtaposition of dissimilar structural and physiognomic types. Rank in edge contrast change was fifth among ERUs.

The 24-percent rise in N2 was the only significant change in richness, dominance, and diversity noted in the Lower Clark Fork ERU. We anticipated the corresponding rise in evenness values (table 19). This ERU ranked sixth in overall change in diversity and richness. Contagion also increased significantly; in fact, the noted change was the fourth largest observed, but interspersion did not change significantly, perhaps owing to our small sample size after poststratification. The Lower Clark Fork displayed the largest overall increase in edge contrast of all ERUs, indicating a significant repatterning of structure and physiognomic condition and grain of the landscape. Further evaluation is needed before these observation can be accepted as representative of the Lower Clark Fork ERU at large because our sample was restricted to subwatersheds of the Upper Coeur d'Alene subbasin, which may not adequately represent the ERU.

The Northern Cascades ERU displayed one of the highest jackknife values for total richness and the highest value for the jackknifed N2 measure; significant increases were noted for all richness and diversity metrics. We expected and observed little or no change in evenness with across-the-board increase in richness, dominance, and diversity (table 19). The Northern Cascades ranked third in overall change in diversity and richness. Change in contagion and interspersion was significant. Decreasing contagion indicated that similar patch types were less likely to be adjacent to one another. Interspersion increase indicated reduced patch sizes and reduced connectivity of patch-type area.

The Northern Glaciated Mountains ERU ranked second in overall change in diversity and richness; richness, dominance, and diversity all increased significantly. Evenness did not change significantly given noted increases in PR, RPR, and N2. The jackknife N2 index of total diversity placed the Northern Glaciated Mountains in the third highest position among ERUs. Decreasing contagion indicated that similar patch types were less likely to be adjacent to one another; increase in edge contrast (AWMECI) was third largest among ERUs. Fire exclusion, timber harvest, and checkerboard ownerships in this ERU all contributed to the changes detected.

The Northern Great Basin and Owyhee Uplands ERUs were among the least diverse in cover-structure patch types from both an average per subwatershed (table 19) and an ERU perspective (table 30). Yet the Northern Great Basin ERU ranked fourth in overall change in diversity and richness. Diversity (SHDI and N2) and dominance (N2) both increased significantly, and as expected, evenness as measured by both MSIEI and R21 measures increased significantly. Decrease in contagion was second only in magnitude to the decrease observed in the Owyhee Uplands.

The Owyhee Uplands ranked ninth overall in richness and diversity changes. Diversity, dominance, and evenness increased in the manner expected, but the Owyhee Uplands was the least diverse among all ERUs from a total N2 perspective (table 30). Radically reduced contagion indicated that similar patch types were less likely than ever to be adjacent to one another, and interspersion increase indicated that patch sizes and connectivity of patch type area had been substantially reduced. Changes in contagion and interspersion were the largest observed among all ERUs. Mean edge contrast increased significantly, indicating increasing juxtaposition of dissimilar structural and physiognomic conditions. The magnitude of change in edge contrast was seventh highest among ERUs. Given the diminutive historical (10.5 percent) and current (11.4 percent) values of AWMECI as compared to values from forest-dominated ERUs, this increase was especially significant. It likely reflects the well-known and widespread conversion and fragmentation of native shrublands by seminative and nonnative grasslands.

The Snake Headwaters ERU ranked eighth overall in richness and diversity mean difference changes. Diversity (SHDI and N2) and dominance (N2) both increased significantly, and as expected, evenness as measured by MSIEI increased significantly. The Snake Headwaters ERU was moderately diverse from a jackknife N2 perspective, but total diversity had declined, albeit nonsignificantly, during the sample period. Contagion decreased, indicating that landscapes had become more fragmented and that similar patch types were less likely to be adjacent to one another.

The Southern Cascades ERU exhibited the greatest overall increase in diversity and richness as measured by ranked and averaged mean difference values, displaying nearly a 40-percent increase in patch richness alone. In fact, richness (PR and RPR), diversity (SHDI and N2), and dominance (N2) all increased significantly, and as expected, evenness as measured by either R21 or MSIEI remained relatively constant. As with most all ERUs, contagion decreased, indicating that landscapes had become more fragmented and that similar patch types were less likely to be adjacent to one another; edge contrast increased significantly, indicating increasing juxtaposition of dissimilar structural and physiognomic conditions. The magnitude of change in edge contrast was second among ERUs.