Table 25—Percentage comparisons of historical and current areas of grass-forb-shrub-bare ground and conifer or hardwood understories for ecological reporting units in the midscale assessment of the interior Columbia River basin

	Area[a]								
	Grass-forb-shrub-bare ground understories			Nonforest-nonwoodland			Conifer or hardwood understories		
Ecological reporting unit	H	C	MD[b]	H	C	MD[b]	H	C	MD[b]
	Percent								
Blue Mountains	16.6	12.6	-4.0*	34.6	31.6	-2.9*	48.8	55.7	6.9*
Central Idaho Mountains	26.6	26.1	-0.5	26.6	26.4	-0.2	46.8	47.5	0.7
Columbia Plateau	14.4	17.7	3.3*	67.2	58.8	-8.5*	18.4	23.6	5.1*
Lower Clark Fork	40.8	32.3	-8.5*	8.3	5.5	-2.8	50.9	62.1	11.2
Northern Cascades	18.4	19.1	0.7	20.9	21.2	0.3	60.7	59.7	-1.0
Northern Glaciated Mountains	21.7	23.1	1.4	19.0	19.2	0.2	59.3	57.7	-1.6
Northern Great Basin	21.9	28.6	6.7*	77.5	70.6	-6.9*	0.6	0.8	0.2
Owyhee Uplands	3.3	4.4	1.1	94.3	92.3	-2.0*	2.4	3.3	0.9*
Snake Headwaters	26.5	20.1	-6.4*	25.3	25.9	0.6	48.2	54.0	5.8*
Southern Cascades	9.9	14.1	4.2	19.5	11.3	-8.2*	70.6	74.6	4.0
Upper Clark Fork	34.3	39.8	5.5*	12.8	13.8	1.0	52.9	46.4	-6.5*
Upper Klamath	10.8	14.5	3.7	41.1	39.7	-1.3	48.1	45.7	-2.4
Upper Snake	1.6	2.7	1.1*	94.7	93.8	-0.9	3.7	3.5	-0.2

[a] H = historical; C = current; MD = mean difference of pairwise comparisons of historical and current subwatersheds.

[b] * indicates statistically significant difference at P≤0.2; all values rounded to 1 decimal place.

Blue Mountains ERU—In the Blue Mountains ERU, forest and woodland tree cover increased in previously nonwooded areas. Area without tree cover (crown cover < 10 percent) declined from 34.6 to 31.6 percent of the ERU area, and area in the 40- to 50-percent crown cover class increased from 17.7 to 21.0 percent of the ERU (table 22 and fig. 39). Area in the 90- to 100-percent crown cover class declined from 7.8 to 5.4 percent. Canopy layering increased across the ERU as well. Area with one canopy layer fell from 16.0 to 12.5 percent, and area with more than two canopy layers increased from 11.6 to 16.4 percent of the ERU area (table 23 and fig. 40). In the historical condition, 65.5 percent of the ERU area was comprised of forest and woodland; 24 percent of that area was single canopy layer forest or woodland. In the current condition, 68.3 percent of the ERU was comprised of forest and woodland; 18.3 percent of that area was single canopy layer forest or woodland. In the historical condition, 17.7 percent of the forest and woodland area was comprised of canopies with more than two layers. In the current condition, 24 percent of the forest and woodland area was comprised of canopies with more than two layers.

Understory area with Douglas-fir or grand fir or white fir, or combinations (Pacific silver fir is absent), increased significantly in the ERU; percentage of area rose from 21.0 to 25.2 percent of the ERU. Understory area with mountain hemlock also increased significantly, but the change was relatively minor (table 24 and figs. 41 and 42). Area with understories classified as “other” (primarily grass and forb, shrub, or bare ground) declined from 16.6 to 12.6 percent of the ERU. These grass, forb, shrub, and bare ground understories currently support trees (table 25). In table 25, we see that area with grass-forb-shrub-bare

ground understories fell and area with conifer or hardwood understories (primarily conifer) increased from 48.8 to 55.7 percent of the ERU area. During the sample period, it is likely that effective fire exclusion and grazing activities allowed conifer understories to develop on 11 percent of historical forest and woodland area.

Central Idaho Mountains ERU—In the Central Idaho Mountains ERU, there was no net increase in forest or woodland area, but total crown cover increased in existing forests and woodlands. Area without tree cover remained unchanged, but area in the 90- to 100-percent crown cover class increased from 12.3 to 15.9 percent, and area in the 40- to 50-percent crown cover class declined from 18.6 to 16.8 percent of the ERU area (table 22 and fig. 39). No significant changes in canopy layers were evident at this reporting scale (table 23 and fig. 40).

Understory area with subalpine fir-Engelmann spruce cover increased significantly in the ERU; percentage of area rose from 14.7 to 16.6 percent of the ERU area (table 24 and figs. 41 and 42). Understory area with mountain hemlock decreased significantly, but the change was relatively minor.

Columbia Plateau ERU—In the Columbia Plateau ERU, forest and woodland tree cover increased in previously nonwooded areas (table 22 and fig. 39). Area without tree cover (crown cover < 10 percent) declined from 67.2 to 58.8 percent of the ERU, and area in the 40- to 50-percent crown cover class increased from 8.8 to 15.4 percent of the ERU. Area in the 90- to 100-percent crown cover class increased from 4.0 to 4.6 percent of the ERU.

Canopy layering also increased in the ERU. Nonforest-nonwoodland area fell from 67.2 to 58.8 percent, thereby confirming previously noted changes in forest and woodland area. Area with one canopy layer increased; percentage of area rose from 14.3 to 17.6 percent, and area with more than two canopy layers increased from 4.3 to 6.4 percent of the ERU (table 23 and fig. 40).

Understory area with Douglas-fir-grand fir-white fir (Pacific silver fir is absent) cover increased significantly in the ERU; percentage of area rose from 2.0 to 2.9 percent of the ERU area. Understory area with subalpine fir-Engelmann spruce cover also increased significantly, but the change was relatively minor (table 24 and figs. 41 and 42). Area with understory juniper increased dramatically; percentage of area rose from 2.3 to 6.5 percent of the ERU. Area with understories classified as "other" (primarily grass-forb, shrub, or bare ground) increased significantly from 14.4 to 17.7 percent of the ERU. As noted in appendix 2, forest area in the Columbia Plateau ERU increased by 3 percent, and woodland area increased by 5.5 percent of the ERU. The observed increase in grass-forb, shrub, or bare ground understory area likely was associated with forest and woodland area expansion; that is, some historical herbland and shrubland areas are wooded in the current condition. In table 25, we see that nonforest-nonwoodland area fell from 67.2 to 58.8 percent, area with grass-forb-shrub-bare ground understories rose from 14.4 to 17.7 percent, and area with conifer or hardwood understories (primarily conifer) increased from 18.4 to 23.6 percent of the ERU. During the sample period, it is likely that effective fire exclusion and grazing activities allowed conifer understories to develop on 15.5 percent of historical forest and woodland area.

Lower Clark Fork ERU—In the Lower Clark Fork ERU, forest and woodland tree cover increased in previously nonwooded areas. Area in the 10- to 30-percent crown cover class declined from 6.3 to 2.7 percent of the ERU, and area in the 40- to 50-percent crown cover class also declined, falling from 21.5 to 9.7 percent. Area in the 90- to 100-percent crown cover class rose more than twofold from 19.7 to 43.4 percent of the ERU area. In the historical vegetation condition, roughly one-quarter of forest patches in the ERU exhibited a total crown cover ≤ 50 percent, and more than three-quarters of forest patches exhibited a total crown coverage ≤ 80 percent (table 22 and fig. 39). In the current condition, patches in the 90- to 100-percent crown cover class were most abundant, representing more than 45 percent of the forest area of the ERU. Canopy layering increased in the ERU as well; percentage of area with one canopy layer fell from 38.7 to 30.0 percent of the ERU, area with two canopy

layers increased from 52.9 to 61.8 percent (ns) (table 23 and fig. 40), and area with more than two canopy layers increased from 0.1 to 2.7 percent of the ERU (ns).

Understory area with western hemlock-western redcedar cover increased significantly in the ERU; percentage of area rose from 13.5 to 17.3 percent of the ERU (table 24 and figs. 41 and 42). Area with understories as "other" (primarily grass-forb, shrub, or bare ground) declined significantly from 40.8 to 32.8 percent of the ERU. These understories currently support trees. In table 25, we see that nonforest-nonwoodland area fell from 8.3 to 5.5 percent (ns), area with grass-forb-shrub-bare ground understories fell from 40.8 to 32.3 percent of the ERU, and area with conifer or hardwood understories (primarily conifer) increased from 50.9 to 62.1 percent of the ERU (ns). During the sample period, it is likely that effective fire exclusion allowed conifer understories to develop on 12 percent of the historical forest area.

Northern Cascades ERU—Overall, there was no significant trend in declining or increasing tree cover in the ERU (table 22 and fig. 39). Area in the 60- to 80-percent crown cover class fell from 33.6 to 30.3 percent (ns), but this decline was evenly offset by increases in the 90- to 100-percent and 40- to 50-percent crown cover classes. Neither were significant changes in canopy layers evident at this reporting scale (table 23 and fig. 40). Understory area with mountain hemlock cover increased significantly in the ERU; percentage of area rose from 0.4 to 0.7 percent of the ERU (table 24 and figs. 41 and 42). Understory area with ponderosa pine understory fell from 8.9 to 7.5 percent (ns). The Northern Cascades ERU is large and diverse with a wide array of biophysical environmental settings. It is likely that differences in crown cover, canopy layering, and understory species cover may be detected at smaller subregional scales.

Northern Glaciated Mountains ERU—No significant changes were observed in tree cover at this reporting scale (table 22 and fig. 39). Area in the 90- to 100-percent crown cover class increased from 21.5 to 24.2 percent, but the change was not significant at $P \leq 0.2$. Canopy layering increased significantly in the ERU. Area with two canopy layers declined from 54.6 to 48.0 percent of the ERU, and area with more than two canopy layers rose from 5.7 to 10.2 percent (table 23 and fig. 40).

Area with ponderosa pine or western larch-lodgepole pine understory cover declined significantly. Percentage of area with ponderosa pine understories fell from 9.9 to 7.4 percent of the ERU, and area with western larch-lodgepole pine understories dropped from 21.4 to 13.6 percent. Compensating increases were observed with Douglas-fir–grand fir and western hemlock-western redcedar understories (table 24 and figs. 41 and 42). Percentage of area with Douglas-fir–grand fir understories increased from 14.9 to 19.2 percent of the ERU area, and area with western hemlock-western redcedar understory cover increased from 2.1 to 5.6 percent of the ERU. Hardwood understory area also increased.

Northern Great Basin ERU—In the Northern Great Basin ERU, forest and woodland tree cover increased in previously nonwooded areas (table 22 and fig. 39). Percentage of area without tree cover (crown cover < 10 percent) declined from 77.5 to 70.6 percent of the ERU, and area in the 40- to 50-percent crown cover class increased from 11.5 to 15.6 percent. Percentage of area in the 60- to 80-percent crown cover class declined from 3.7 to 3.1 percent. Concurrent with increasing forest and woodland tree cover, area with one canopy layer rose from 21.9 to 28.9 percent of the ERU (table 23 and fig. 40).

Area with understories classified as "other" (primarily grass-forb, shrub, or bare ground) increased significantly from 21.9 to 28.6 percent of the ERU (table 24 and figs. 41 and 42). As noted in appendix 2, woodland area in the Northern Great Basin ERU increased from 15.3 to 22.2 percent of the ERU. The observed increase in grass-forb, shrub, or bare ground understory cover likely was associated with woodland area expansion; that is, some historical herbland and shrubland areas are wooded in the current condition (see also table 25).

Owyhee Uplands ERU—In the Owyhee Uplands ERU, woodland tree cover increased in previously nonwooded areas. Percentage of area without tree cover (crown cover < 10 percent) declined from 94.3 to 92.3 percent of the ERU, and percentage of area in the 10- to 30-percent crown cover class increased from 4.2 to 5.4 percent (table 22 and fig. 39). Area in the 40- to 50-percent crown cover class also increased, rising from 1.3 to 2.2 percent of the ERU area. Canopy layering also increased significantly in the ERU. Percentage of area with two canopy layers increased from 2.1 to 3.0 percent of the ERU (table 23 and fig. 40). Area with understory juniper cover also increased; percentage of area rose from 2.2 to 3.2 percent of the ERU (tables 24 and 25 and figs. 41 and 42).

Snake Headwaters ERU—In the Snake Headwaters ERU, there was no net increase in forest or woodland area, but unlike most other ERUs, total crown cover declined in existing forests and woodlands (table 22 and fig. 39). Percentage of area without tree cover remained unchanged, but area in the 90- to 100-percent crown cover class fell from 11.5 to 7.5 percent of the ERU, and percentage of area in the 40- to 50-percent crown cover class rose from 15.8 to 19.2 percent of the ERU. Canopy layering increased in the ERU (table 23 and fig. 40). Percentage of area with a single canopy layer declined from 26.4 to 19.7 percent of the ERU and area with two canopy layers increased from 45.1 to 50.6 percent of the ERU (ns).

Percentage of area with western larch-lodgepole pine understory cover fell from 13.5 to 9.0 percent of the ERU (ns), and area with subalpine fir-Engelmann spruce understory cover increased; percentage of area rose from 22.7 to 32.8 percent of the ERU, representing a 44-percent increase during the sample period (table 24 and figs. 41 and 42). Percentage of area with understories classified as “other” (primarily grass-forb, shrub, or bare ground) decreased significantly from 26.5 to 20.5 percent of the ERU. These understories currently support trees. In table 25, we see that percentage of area with grass-forb-shrub-bare ground understories fell by 6.4 percent, and area with conifer or hardwood understories (primarily conifer) increased by 5.8 percent, rising from 48.2 to 54.0 percent of the ERU area. It is likely that fire exclusion and domestic livestock grazing practices enabled conifer understories to develop on 7.8 percent of historical forest and woodland area.

Southern Cascades ERU—Forest and woodland tree cover increased in previously nonwooded areas. Percentage of area without tree cover (crown cover < 10 percent) fell sharply from 19.5 to 11.3 percent of the ERU, area in the 10- to 30-percent crown cover class increased from 8.0 to 12.9 percent, and area in the 90- to 100-percent crown cover class increased from 0.2 to 3.5 percent of the ERU (table 22 and fig. 39).

Perhaps the most significant change in canopy layering occurring among all ERUs was that observed for the Southern Cascades ERU. Nonforest-nonwoodland area fell sharply from 19.5 to 11.3 percent of the ERU, and area with more than two canopy layers increased by a compensating amount from 10.7 to 19.6 percent. Area with a single canopy layer also increased, but the change was not significant; percentage of area rose from 9.7 to 14.1 percent of the ERU. Area with two canopy layers fell from 60.0 to 55.0 percent but the change was not significant (table 23 and fig. 40).

Upper Clark Fork ERU—There was no net increase in forest or woodland area, but total crown cover declined in existing forests and woodlands (table 22 and fig. 39). Area without tree cover remained unchanged, but percentage of area in the 60- to 80-percent crown cover class fell from 45.3 to 41.2 percent of the ERU, and area in the 10- to 30-percent crown cover class rose from 7.4 to 9.5 percent. Canopy layering also declined in the Upper Clark Fork ERU (table 23 and fig. 40). Percentage of area with two layers and more than two layers declined significantly; percentage of area fell from 41.0 to 37.2 percent, and from 13.8 to 11.4 percent, respectively. Percentage of area with a single canopy layer rose sharply from 32.4 to 37.7 percent of the ERU.

Table 26—Percentage comparison of area of forest and woodland in dead tree and snag abundance classes

	Area[a]					
	No dead trees or snags apparent			< 10 percent of trees dead or snags		
Ecological reporting unit	H	C	MD[b]	H	C	MD[b]
	Percent					
Blue Mountains	44.5	41.2	-3.3	20.1	20.2	0.1
Central Idaho Mountains	56.5	46.3	-10.2*	15.3	24.3	9.0*
Columbia Plateau	22.5	26.2	3.8*	10.2	2.7	2.5
Lower Clark Fork	66.0	62.7	-3.3	24.5	31.7	7.2
Northern Cascades	66.7	46.9	-19.8*	11.6	28.9	17.3*
Northern Glaciated Mountains	61.7	47.9	-13.8*	14.8	28.7	13.9*
Northern Great Basin	22.5	29.4	6.9*	0.0	0.0	0.0
Owyhee Uplands	4.9	6.4	1.4*	0.8	1.4	0.6
Snake Headwaters	51.8	34.2	-17.5*	22.0	23.7	1.6
Southern Cascades	76.8	76.9	0.1	3.7	9.9	6.2*
Upper Clark Fork	74.3	80.3	6.0*	10.6	5.2	-5.4*
Upper Klamath	21.7	24.1	2.4	36.7	34.1	-2.6*
Upper Snake	4.3	4.0	-0.3	1.0	1.7	0.8

[a] H = historical; C = current; MD = mean difference of pairwise comparisons of historical and current subwatersheds.

[b] * indicates statistically significant difference at P≤0.2; all values rounded to 1 decimal place.

The ERU area with ponderosa pine or western larch-lodgepole pine understory cover declined significantly. Percentage of area with ponderosa pine understories fell from 7.8 to 5.8 percent, and area with western larch-lodgepole pine understories dropped from 32.5 to 24.0 percent (table 24 and figs. 41 and 42). Area with Douglas-fir–grand fir understory cover increased significantly in the ERU; percentage of area rose from 5.4 to 8.4 percent of the ERU. Percentage of area with understories classified as "other" (primarily grass-forb, shrub, or bare ground) increased from 34.3 to 39.8 percent of the ERU. In table 25, we see that area with grass-forb-shrub-bare ground understories rose, and area with conifer or hardwood understories (primarily conifer) declined. During the sample period, it is likely that timber harvest activities reduced conifer understories on 7 percent of the historical forest and woodland area.

Upper Klamath ERU—In the Upper Klamath ERU, there was no net increase in forest or woodland area, but total crown cover declined in existing forests and woodlands (table 22 and fig. 39). Percentage of area without tree cover remained essentially unchanged, but area in the 60- to 80-percent crown cover class fell from 27.4 to 19.9 percent, and area in the 40- to 50-percent crown cover class rose sharply from 17.5 to 26.1 percent. Canopy layering in the Upper Klamath generally declined, but none of the observed changes was significant at P≤0.2 (table 23 and fig. 40).

Upper Snake ERU—In the Upper Snake ERU, forest tree cover increased slightly but significantly in previously nonwooded areas (table 22 and fig. 39). Percentage of area without tree cover (crown cover < 10 percent) remained unchanged, and area in the 40- to 50-percent crown cover class increased from 1.9 to 2.4 percent of the ERU area. Concurrent with increasing tree cover, forest area with a single canopy layer rose from 1.6 to 2.7 percent of the ERU (table 23 and fig. 40). Percentage of area with understories classified as "other" (primarily grass-forb, shrub, or bare ground) increased from 1.6 to 2.7 percent of the ERU (see also table 25).

for ecological reporting units in the midscale assessment of the interior Columbia River basin

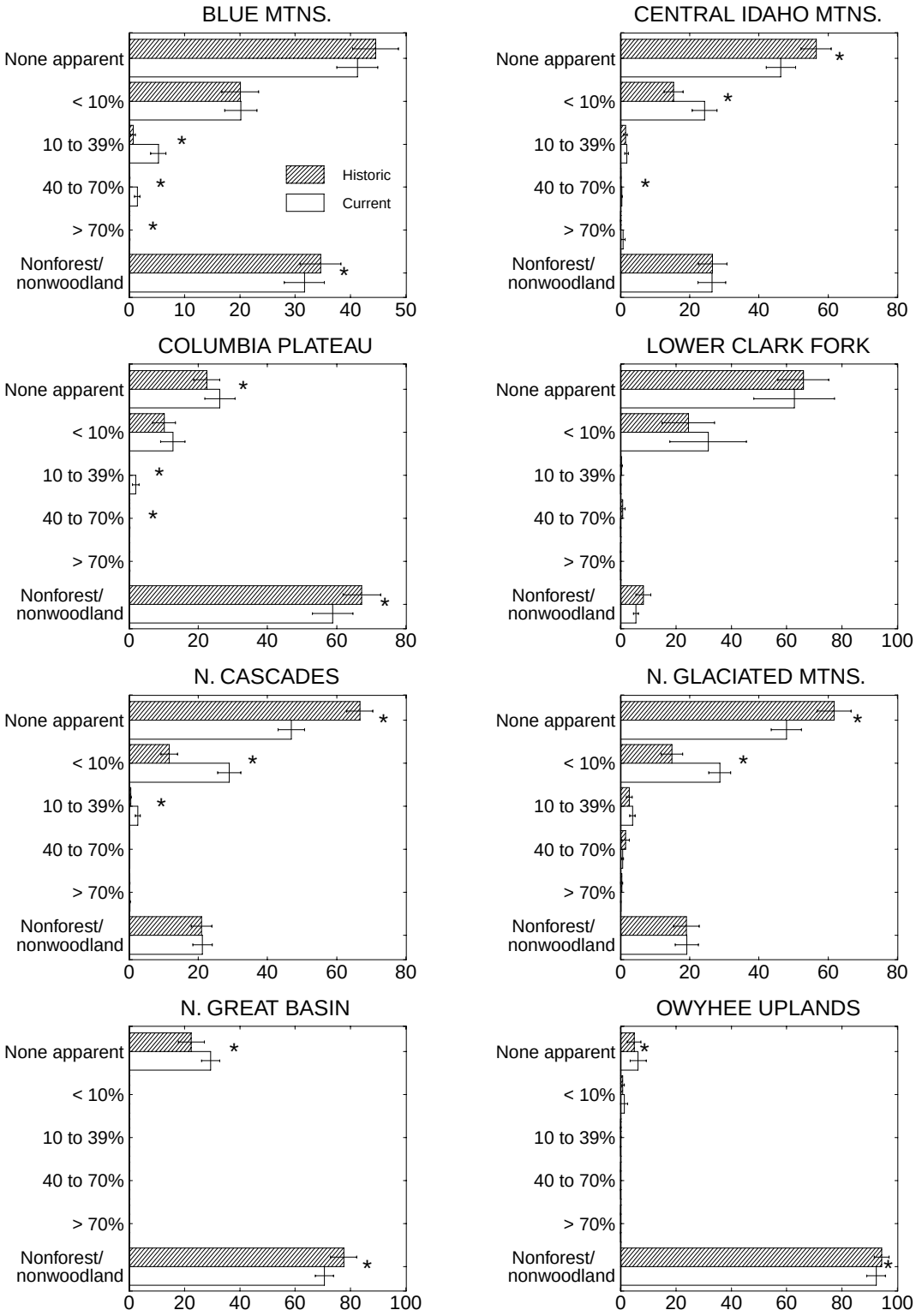
Area[a]											
10 to 39 percent of trees dead or snags			40 to 70 percent of trees dead or snags			> 70 percent of trees dead or snags			Nonforest-nonwoodland		
H	C	MD[b]	H	C	MD[b]	H	C	MD[b]	H	C	MD[b]
Percent											
0.8	5.3	4.5*	0.1	1.5	1.4*	0.0	0.1	0.1*	34.6	31.6	-2.9*
1.5	1.8	0.4	0.1	0.4	0.2*	0.0	0.8	0.8	26.6	26.4	-0.2
0.1	2.0	1.8*	0.0	0.2	0.2*	0.0	0.2	0.2	67.2	58.8	-8.4*
0.4	0.1	-0.3	0.9	0.0	-0.9	0.0	0.0	0.0	8.3	5.5	-2.8
0.5	2.6	2.1*	0.2	0.1	0.0	0.2	0.2	0.1	20.9	21.2	0.3
2.6	3.5	0.8	1.5	0.6	-0.9	0.4	0.1	-0.2	19.0	19.2	0.2
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.5	70.6	-6.9*
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	94.3	92.3	-2.0*
0.8	12.9	12.0*	0.0	1.2	1.2*	0.0	2.1	2.1*	25.3	25.9	0.6
0.0	1.4	1.3*	0.0	0.5	0.5	0.0	0.1	0.1*	19.5	11.3	-8.2*
1.8	0.2	-1.6*	0.1	0.1	0.0	0.4	0.3	-0.1	12.8	13.8	1.0
0.5	1.1	0.6	0.0	1.0	0.9	0.0	0.0	0.0	41.1	39.7	-1.3
0.0	0.2	0.2*	0.0	0.0	0.0	0.0	0.1	0.1	94.7	93.8	-0.9

Dead Tree and Snag Abundance

In this section, we report on changes in dead tree and snag abundances to evaluate direct effects of insect and pathogen infestation and mortality and indirect effects of fire exclusion, dead tree salvage, and timber harvest during the last half century. Our null hypothesis was no significant difference in dead tree and snag abundance between historical and current photointerpreted vegetation conditions. We speculated that fire prevention and suppression activities, salvage logging, and selective timber harvesting created increased abundance of snags and dead trees in sapling, pole, and small-tree size classes. We further speculated that abundance of medium and large dead trees and snags declined with widespread decline of live medium and large trees (see also tables 20 and 21).

Table 26 and figure 43 display changes during the sample period in percentage of area of five dead tree and snag abundance classes. Dead tree and snag classes were none apparent, < 10 percent of trees dead or snags, 10 to 39 percent of trees dead or snags, 40 to 70 percent of trees dead or snags, and > 70 percent of trees dead or snags.

Dead tree and snag abundance increased significantly in the Blue Mountains, Central Idaho Mountains, Columbia Plateau, North Cascades, Northern Glaciated Mountains, Snake Headwaters, and Southern Cascades ERUs and declined significantly in the Upper Clark Fork and Upper Klamath ERUs. Two patterns of change were observed. High concentrations of dead trees within patches (≥ 10 percent of trees dead or snags) were found in the Blue Mountains, Snake Headwaters, and Southern Cascades ERUs, but affected areas comprised less than 10 to 15 percent of the ERU area. In the Central Idaho Mountains, Northern Cascades, and Northern Glaciated Mountains ERUs, dead trees were less concentrated within patches (< 10 percent of trees dead or snags than in the aforementioned ERUs), but this condition occurred over relatively large areas of each ERU, affecting 10 to 20 percent of the land area.


BLUE MTNS.
CENTRAL IDAHO MTNS.
COLUMBIA PLATEAU
LOWER CLARK FORK
N. CASCADES
N. GLACIATED MTNS.
N. GREAT BASIN
OWYHEE UPLANDS
None apparent
< 10%
10 to 39%
40 to 70%
> 70%
Nonforest/ nonwoodland
Historic
Current
0
10
20
30
40
50
60
80
100

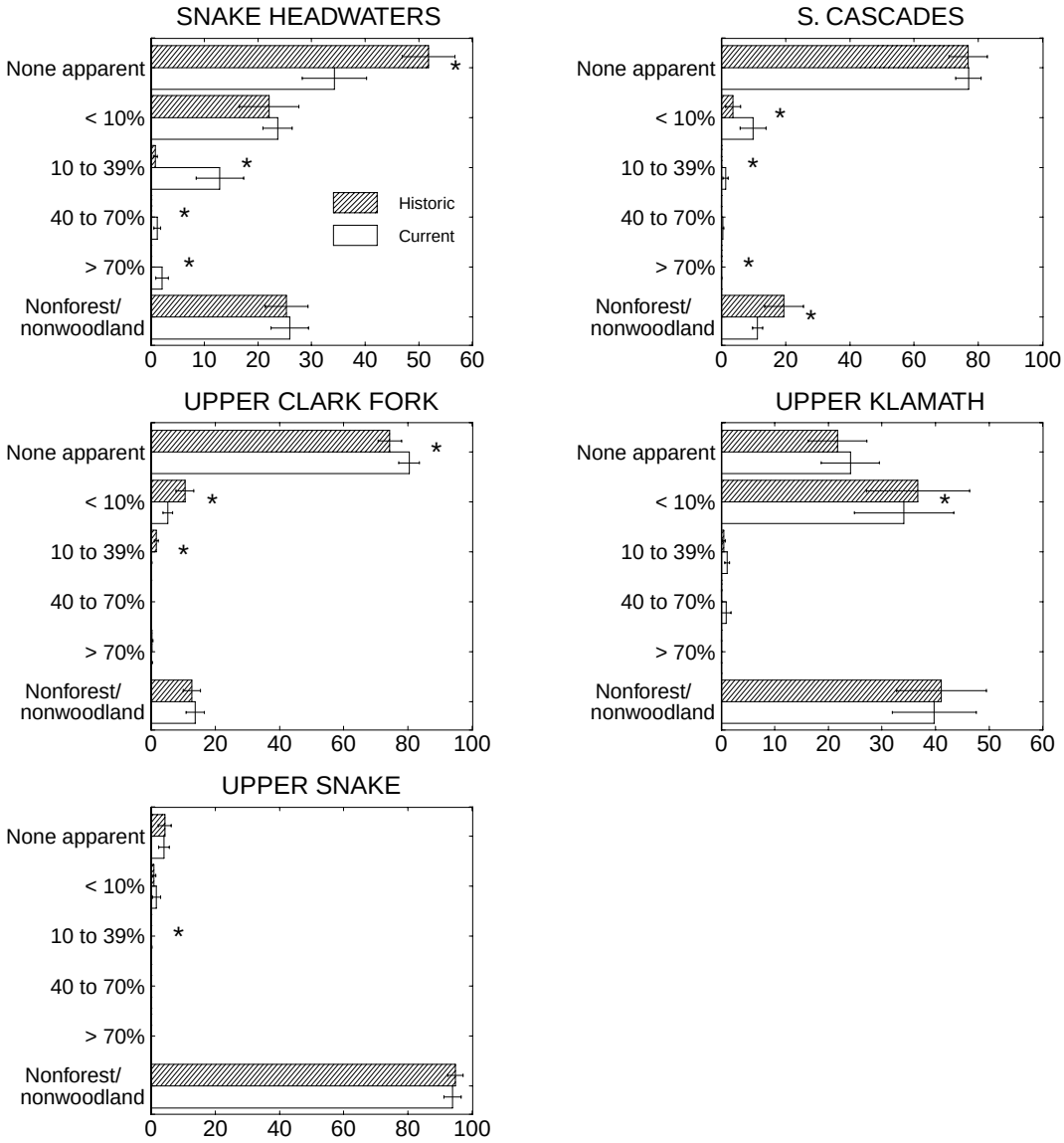


Figure 43—Historical and current distribution of forest and woodland dead tree and snag abundance classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Dead tree and snag classes were none apparent, < 10 percent of trees dead or snags, 10 to 39 percent of trees dead or snags, 40 to 70 percent of trees dead or snags, and > 70 percent of trees dead or snags.

Table 27—Percentage comparison of area of forest and woodland in visible logging activity classes for

	Area[a]					
	No logging apparent			Regeneration harvest		
Ecological reporting unit	H	C	MD[b]	H	C	MD[b]
	Percent					
Blue Mountains	51.4	49.0	-2.5	3.9	5.1	1.2
Central Idaho Mountains	70.5	67.9	-2.6*	0.5	2.7	2.2*
Columbia Plateau	25.1	27.5	2.4	1.4	1.5	0.1
Lower Clark Fork	67.5	67.0	-0.6	2.3	9.5	7.2*
Northern Cascades	71.3	61.4	-9.9*	0.4	4.1	3.7*
Northern Glaciated Mountains	74.0	59.4	-14.6*	2.3	7.9	5.6*
Northern Great Basin	22.5	29.4	6.9*	0.0	0.0	0.0
Owyhee Uplands	5.7	7.7	2.0*	0.0	0.0	0.0
Snake Headwaters	74.7	72.4	-2.3	0.0	0.1	0.1*
Southern Cascades	65.1	54.7	-10.3*	5.5	7.5	2.0
Upper Clark Fork	77.0	63.8	-13.2*	5.5	11.6	6.1*
Upper Klamath	48.9	35.2	-13.7*	1.0	3.8	2.8*
Upper Snake	4.1	6.0	1.9*	0.0	0.0	-0.0

[a] H = historical; C = current; MD = mean difference of pairwise comparisons of historical and current subwatersheds.

[b] * indicates statistically significant difference at P≤0.2; all values rounded to 1 decimal place.

Area Affected by Visible Logging Activity

In this section, we report on changes in area affected by visible logging activity to evaluate extent and effects of timber harvest activities during the sample period. Our null hypothesis was no significant difference in percentage of area within logging activity classes between historical and current vegetation conditions. We hypothesized that area affected by selective and regeneration harvest activities would increase during the sample period. Table 27 and figure 44 display changes in percentage of area of five visible logging entry classes. Logging entry classes were no logging apparent, regeneration harvest, selective harvest, thinned, and small patch clearcut.

As would be expected, logging activity increased significantly in all forested ERUs. Percentage of area with no visible logging activity declined significantly in 6 of 13 ERUs, and increased in 3 herbland- and shrubland-dominated ERUs. The most commonly increasing logging activity was selective harvesting, which increased significantly in the Blue Mountains, Columbia Plateau, Northern Cascades, Northern Glaciated Mountains, Snake Headwaters, Southern Cascades, Upper Clark Fork, and Upper Klamath ERUs and declined in the Lower Clark Fork (ns) and Upper Snake ERUs. In all but one forested ERU, selective harvesting had affected less than 10 percent of the historical condition. But, in the Lower Clark Fork ERU, nearly 22 percent of the area had been affected by selective harvesting in the historical condition. During the sample period, apparent selective harvested area increased from 9.6 to 13.2 percent of the ERU in the Blue Mountains, from 6.1 to 11.3 percent in the Columbia Plateau, from 7.2 to 11.5 percent in the Northern Cascades, from 4.5 to 11.4 percent in the Northern Glaciated Mountains, from 0 to 0.3 percent in the Snake Headwaters, from 9.2 to 23.2 percent in the Southern Cascades, from 4.6 to 9.7 percent in the Upper Clark Fork, and from 7.0 to 19.3 percent in the Upper Klamath ERU.

ecological reporting units in the midscale assessment of the interior Columbia River basin

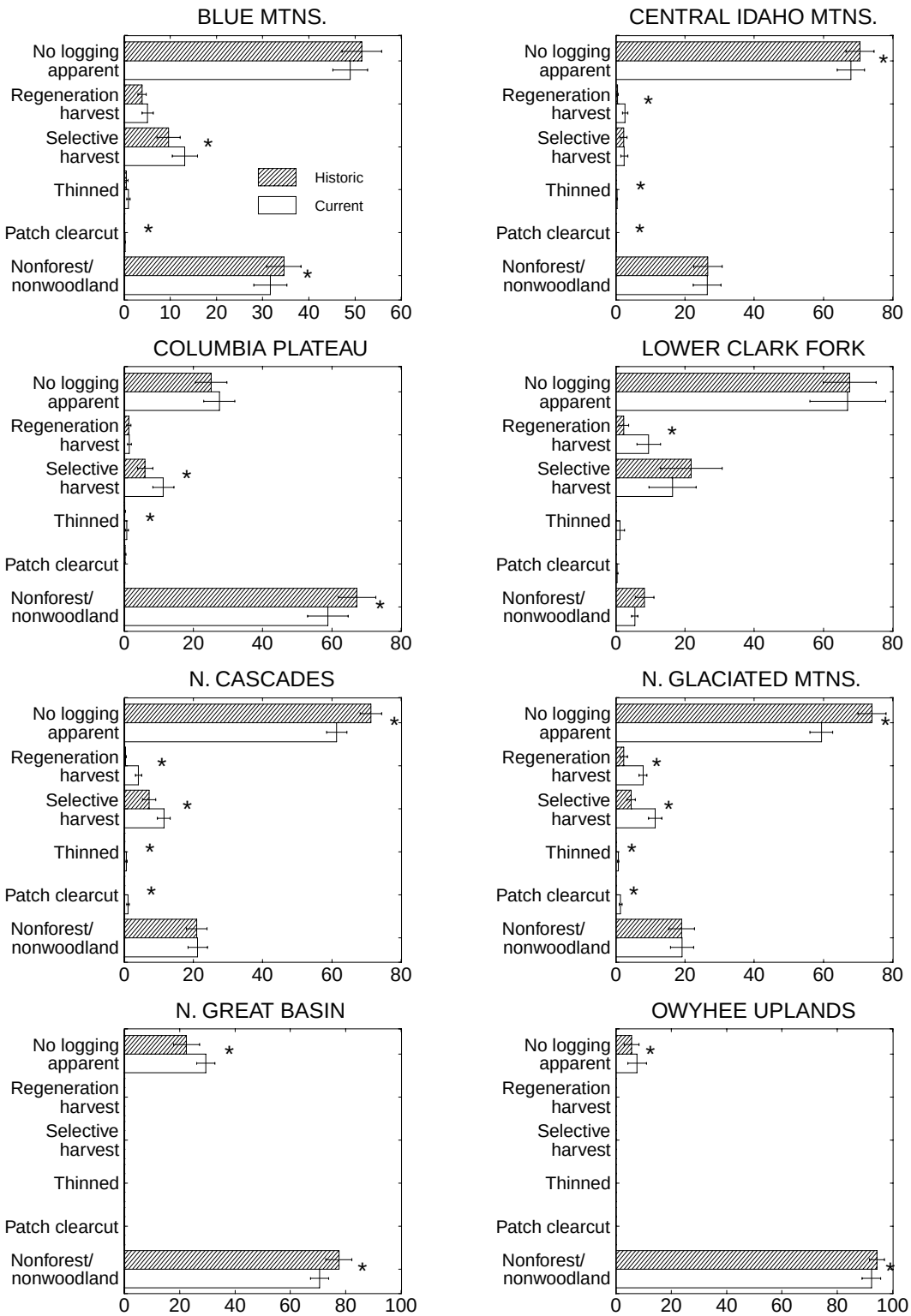
Area[a]											
Selective harvest			Thinned			Patch clearcut			Nonforest-nonwoodland		
H	C	MD[b]	H	C	MD[b]	H	C	MD[b]	H	C	MD[b]
Percent											
9.6	13.2	3.5*	0.5	0.9	0.4	0.0	0.2	0.2*	34.6	31.6	-2.9*
2.3	2.5	0.2	0.0	0.4	0.3*	0.0	0.1	0.1*	26.6	26.4	-0.2
6.1	11.3	5.3*	0.2	0.8	0.6*	0.3	0.1	-0.2	67.2	58.8	-8.4*
21.8	16.4	-5.5	0.0	1.3	1.2	0.0	0.4	0.4	8.3	5.5	-2.8
7.2	11.5	4.3*	0.1	0.7	0.6*	0.0	1.1	1.1*	20.9	21.2	0.3
4.5	11.4	6.9*	0.0	0.7	0.7*	0.0	1.4	1.4*	19.0	19.2	0.2
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.5	70.6	-6.9*
0.0	0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	94.3	92.3	-2.0*
0.0	0.3	0.3*	0.0	0.0	0.0	0.0	1.3	1.3*	25.3	25.9	0.6
9.2	23.2	14.0*	0.7	2.8	2.1*	0.0	0.5	0.5*	19.5	11.3	-8.2*
4.6	9.7	5.1*	0.0	0.6	0.6*	0.0	0.5	0.5*	12.8	13.8	1.0
7.0	19.3	12.2*	2.0	1.9	0.0	0.0	0.1	0.1	41.1	39.7	-1.3
1.2	0.2	-1.1*	0.0	0.0	0.0	0.0	0.0	0.0	94.7	93.8	-0.9

Area affected by regeneration harvests increased most significantly in the Central Idaho Mountains, Lower Clark Fork, Northern Cascades, Northern Glaciated Mountains, Upper Clark Fork, and Upper Klamath ERUs. During the sample period, apparent regeneration-harvested area increased from 0.5 to 2.7 percent of the ERU in the Central Idaho Mountains, from 2.3 to 9.5 percent in the Lower Clark Fork, from 0.4 to 4.1 percent in the Northern Cascades, from 2.3 to 7.9 percent in the Northern Glaciated Mountains, from 0 to 0.1 percent in the Snake Headwaters, from 5.5 to 11.6 percent in the Upper Clark Fork, and from 1.0 to 2.8 percent in the Upper Klamath ERU. Thinned and small patch clearcut areas also increased significantly in about one-half of the ERUs, but affected areas were considerably smaller than those affected by regeneration and selective harvests.

In the Blue Mountains' historical vegetation coverage, 65.5 percent of the land area of the ERU was forested or woodland (appendix 2), 78.5 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 21.4 percent of the forest and woodland area was visibly logged (table 27). In our current vegetation coverage, 68.3 percent of the land area was forested or in woodland, 71.7 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 28.4 percent of the forest and woodland area was visibly logged.

Historically, 73.5 percent of the land area of the Central Idaho Mountains ERU was forested or woodland, 95.9 percent of the forest and woodland area exhibited no sign of visible logging activity, and 3.8 percent of the forest and woodland area was visibly logged. In our current vegetation coverage, 73.5 percent of the land area was again forested or in woodland, 92.4 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 7.8 percent of the forest and woodland area was visibly logged.

For the Columbia Plateau ERU, 32.8 percent of the land area was forested or woodland in historical vegetation coverage, 76.5 percent of the forest and woodland area exhibited no sign of visible logging activity, and 24.4 percent of the forest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N. CASCADES
N. GLACIATED MTNS.
N. GREAT BASIN
OWYHEE UPLANDS
No logging apparent
Regeneration harvest
Selective harvest
Thinned
Patch clearcut
Nonforest/ nonwoodland
Historic
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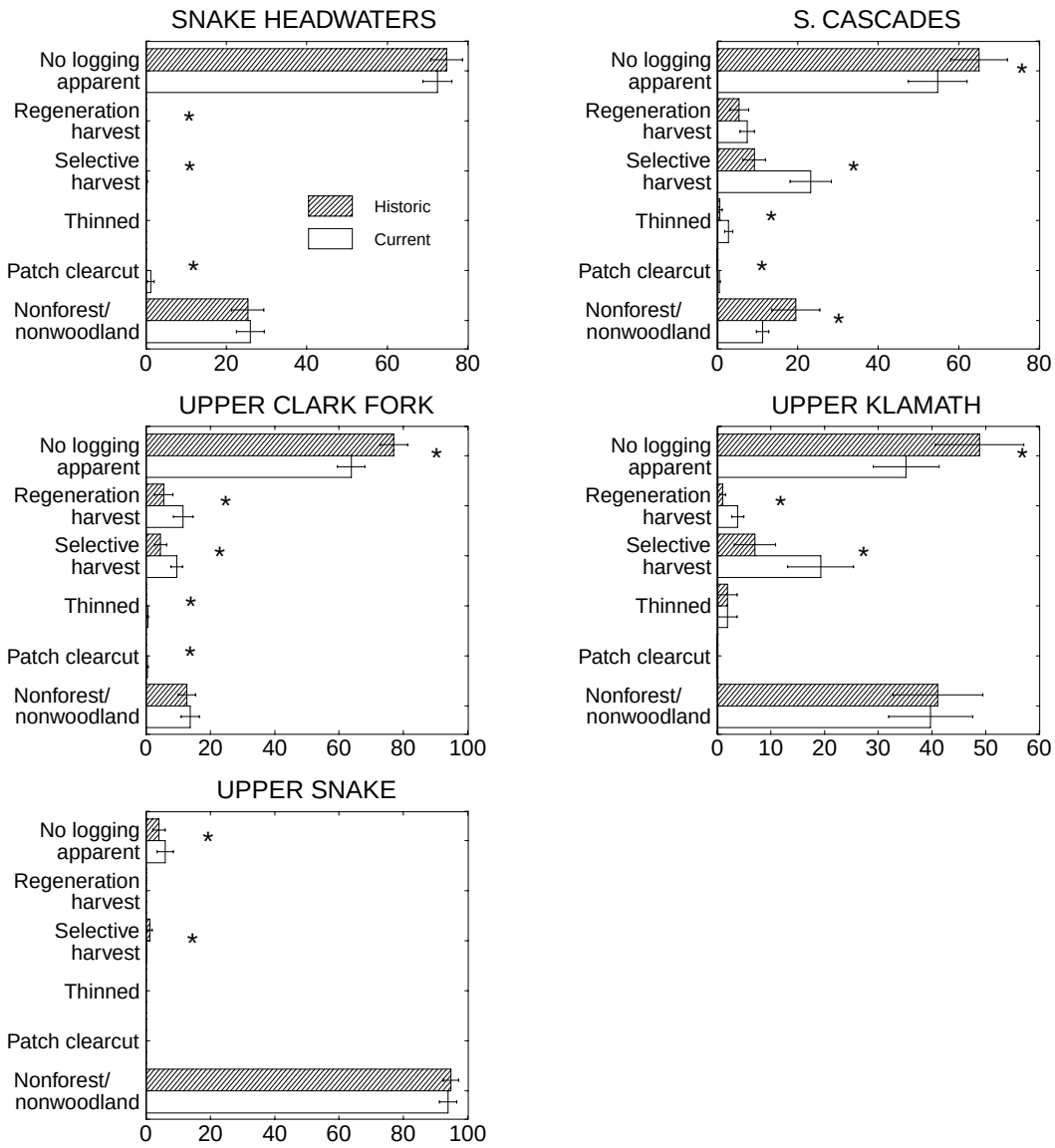

Figure 44—Historical and current distribution of forest and woodland apparent logging entry classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Logging entry classes were no logging apparent, regeneration harvest, selective harvest, thinned, patch clearcut, and nonforest-nonwoodland.

and woodland area was visibly logged. In the current condition, 41.3 percent of the land area was forested or in woodland, 66.6 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 33.2 percent of the forest and woodland area was visibly logged.

Historically, 93.6 percent of the land area of the Lower Clark Fork ERU was forested or woodland, 72.1 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 25.7 percent of the forest and woodland area was visibly logged. In the current condition, 95.1 percent of the land area was forested or in woodland, 70.5 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 29 percent of the forest and woodland area was visibly logged.

For the Northern Cascades ERU historical vegetation coverage, 79.1 percent of the land area was forested or in woodland, 90.1 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 9.7 percent of the forest and woodland area was visibly logged. In the current condition, 78.9 percent of the land area was forested or in woodland, 77.8 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 22.1 percent of the forest and woodland area was visibly logged.

In the Northern Glaciated Mountains ERU, 81 percent of the land area was forested or woodland in historical vegetation coverage, 91.4 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 8.4 percent of the forest and woodland area was visibly logged. In the existing condition, 80.8 percent of the land area was forested or in woodland, 73.5 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 26.5 percent of the forest and woodland area was visibly logged.

Historically, 74.7 percent of the land area of the Snake Headwaters ERU was forested or woodland, and no forest and woodland area exhibited any sign of visible logging activity. In the current condition, 74.1 percent of the land area was forested or in woodland, 97.7 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 2.3 percent of the forest and woodland area was visibly logged.

In the Southern Cascades ERU, 80.5 percent of the land area was forested or woodland in historical vegetation coverage, 80.9 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 19.1 percent of the forest and woodland area was visibly logged. In the current condition, 88.7 percent of the land area was forested or in woodland, 61.7 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 38.3 percent of the forest and woodland area was visibly logged.

Nearly 90 percent (87.2) of the land area of the Upper Clark Fork ERU was forested or woodland in historical vegetation coverage, 88.3 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 11.6 percent of the forest and woodland area was visibly logged. In the current condition, 86.2 percent of the land area was forested or in woodland, 74 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 26 percent of the forest and woodland area was visibly logged.

Finally, in the Upper Klamath ERU historical vegetation coverage, 58.9 percent of the land area was forested or woodland, 83 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 17 percent of the forest and woodland area was visibly logged. In the existing condition, 60.3 percent of the land area was forested or in woodland, 58.4 percent of the forest and woodland area exhibited no apparent sign of visible logging activity, and 41.6 percent of the forest and woodland area was visibly logged.

Table 28—Comparison of riparian-wetland area abundance in ecological reporting units in the midscale assessment of the interior Columbia River basin

	Area[a]					
	Riparian or wetland area			Not a riparian or wetland area		
Ecological reporting unit	H	C	MD[b]	H	C	MD[b]
	Percent			*Percent*		
Blue Mountains	3.3	5.3	2.0*	96.7	94.7	-2.0*
Central Idaho Mountains	2.8	3.7	0.9*	97.2	96.3	-0.9*
Columbia Plateau	3.5	2.5	-1.0*	96.5	97.5	1.0*
Lower Clark Fork	3.3	3.6	0.3*	96.7	96.4	-0.3*
Northern Cascades	5.5	7.2	1.7*	94.5	92.8	-1.7*
Northern Glaciated Mountains	4.5	4.6	0.1	95.6	95.4	-0.1
Northern Great Basin	4.2	2.6	-1.5	95.8	97.4	1.5
Owyhee Uplands	1.5	1.1	-0.4	98.5	98.9	0.4
Snake Headwaters	5.9	6.5	0.5	94.1	93.5	-0.5
Southern Cascades	4.1	6.1	1.9*	95.9	93.9	-1.9*
Upper Clark Fork	8.0	7.5	-0.5	92.0	92.5	0.5
Upper Klamath	15.1	12.7	-2.4	84.9	87.3	2.4
Upper Snake	0.3	0.5	0.1	99.7	99.5	-0.1

[a] H = historical; C = current; MD = mean difference of pairwise comparisons of historical and current subwatersheds.

[b] * indicates statistically significant difference at $P \leq 0.2$; all values rounded to 1 decimal place.

Riparian and Wetland Area

In this section, we report on changes in distribution of riparian and wetland area to evaluate extent and effects of timber harvest activities and fire exclusion during the sample period. Our null hypothesis was no significant difference in percentage of riparian or wetland area between historical and current vegetation conditions. We speculated that riparian and wetland area within forested ERUs declined as a result of increased density and areal extent of forests and woodlands and their dewatering effects on wet areas. We further speculated that riparian and wetland area in nonforest also declined as a result of extensive agricultural use of historical herbland and shrubland riparian areas and ditching efforts in wetlands. Table 28 and figure 45 display change in riparian and wetland area during the sample period.

As was expected, riparian and wetland area declined in ERUs with significant nonforest area, but surprisingly, area increased in forested ERUs. We suspect that the observed increase in riparian and wetland area in forested ERUs was a function of two unrelated factors. First, in the absence of more regular fire disturbance to both riparian and adjacent upslope environments, differences between valley bottom environments and adjacent slopes had time to develop and be expressed over a period of six or seven decades without fire. Camp (1995) and Camp and others (1997) show that 74 percent of the riparian environments in the Wenatchee Mountains of Washington display the fire regime of adjacent side slopes. Second, scale of photos of current vegetation conditions was somewhat larger than that for the historical conditions, and most historical photography was black and white. Steps were taken to minimize effects of these differences on remotely sensed interpretations, but interpreters noted that interpreting vegetation attributes from black and white, 1:20,000-scale, historical photographs was somewhat more difficult than interpreting 1:12,000-scale, current color photography. It is therefore possible that photointerpreters were

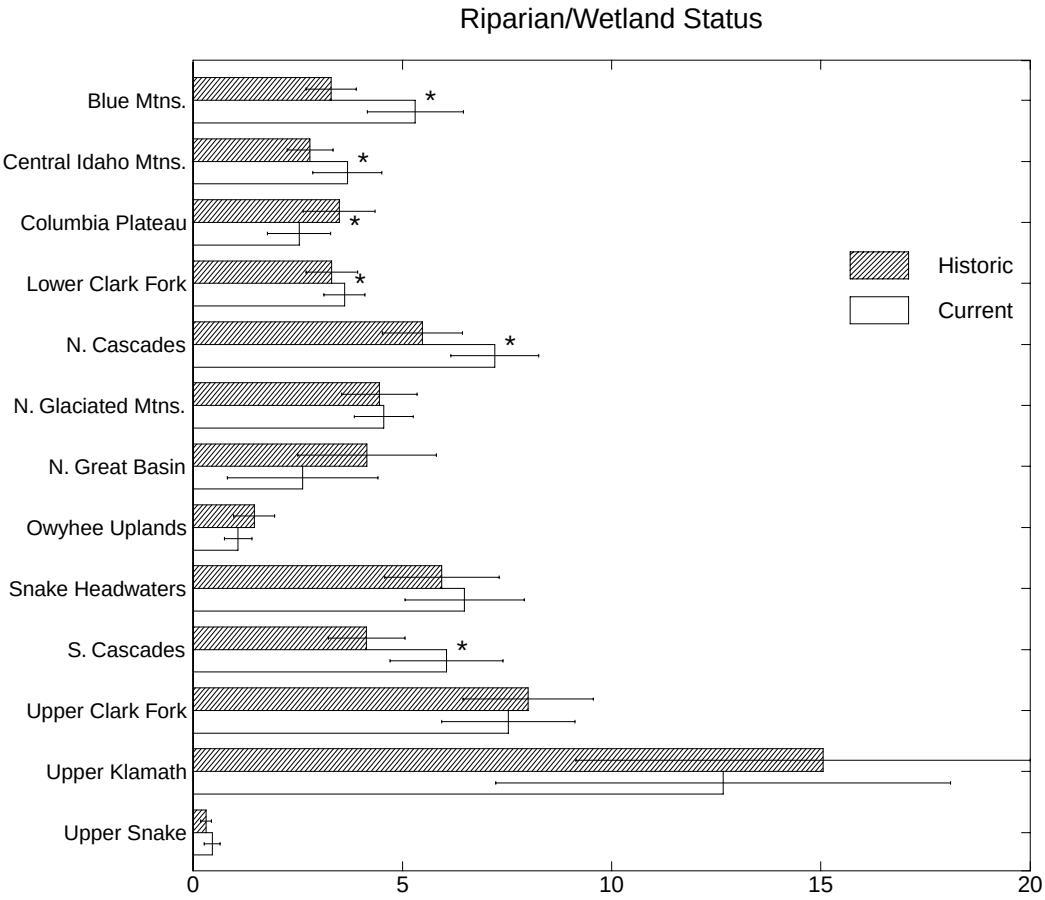

Figure 45—Historical and current distribution of riparian and wetland area expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions.

able to see more riparian and wetland areas in the current photography. We believe that this source of error was minimized, though, because high-quality mirrored stereoscopes were used with adequate lighting and variable ocular magnification.

Riparian and wetland area increased significantly in the Blue Mountains, Central Idaho Mountains, Lower Clark Fork, Northern Cascades, and Southern Cascades ERUs and decreased significantly in the Columbia Plateau ERU. During the sample period, riparian and wetland area increased from 3.3 to 5.3 percent of the ERU in the Blue Mountains, from 2.8 to 3.7 percent in the Central Idaho Mountains, from 3.3 to 3.6 percent in the Lower Clark Fork, from 5.5 to 7.7 percent in the Northern Cascades, and from 4.1 to 6.1 percent in the Southern Cascades. Riparian and wetland area declined from 3.5 to 2.5 percent of the ERU in the Columbia Plateau. A general trend of declining riparian and wetland area also was noted in the Northern Great Basin, Owyhee Uplands, Upper Clark Fork, and Upper Klamath ERUs, but changes were not significant at this reporting scale.

Vulnerability of Forest Landscapes to Potential Insect and Pathogen Disturbances

In this section, we describe significant change in area and connectivity of patch types between historical and current vegetation conditions, where patch types were insect and pathogen disturbance vulnerability classes (hereafter, vulnerability classes). Our null hypothesis was no significant difference in area or connectivity of area vulnerable to insect and pathogen disturbances between historical and current vegetation conditions. We speculated that both significant increases and declines in vulnerability would be observed as a consequence of timber harvest, domestic livestock grazing activities, and fire exclusion. All results are summarized by ERU, and ecologically significant change is the primarily emphasis. Appendix 3 provides complete tabular results of all analyses summarized in this section. Comparisons among ERUs are provided in the "Discussion."

Vulnerability to potential insect and pathogen disturbances changed less than expected because variation among paired subwatershed samples was considerable at the ERU scale. Large changes in vulnerability to insect and pathogen disturbances were common at the subwatershed scale, thereby indicating that statistical pooling at the subwatershed scale was more appropriate for reporting midscale trends in vulnerability.

Blue Mountains ERU—Subbasins sampled within the Blue Mountains ERU (figs. 12 to 14 and 16) included the Burnt (BUR), Lower Grande Ronde (LGR), Silvies (SIL), Upper Grande Ronde (UGR), Upper John Day (UJD), and Wallowa (WAL). Among these subbasins, 46 historical and current subwatershed pairs were sampled.

Insect disturbance vulnerabilities— *Defoliators*—There was no significant change in percentage of area vulnerable to western spruce budworm disturbance at this reporting scale (fig. 46), but connectivity of vulnerable area declined (appendix 3). Patch density of the high vulnerability class increased from 12.4 to 14.7 patches per 10 000 ha, and mean patch size declined from an average of 568.4 to 516.4 ha (ns). Loss of grand fir and white fir cover and increased area in Douglas-fir cover were apparently compensating effects of management (appendix 2).

Barkbeetles—Area vulnerable to the Douglas-fir beetle disturbance increased, and connectivity of vulnerable area also increased. Percentage of area in the high vulnerability class rose from 5.2 to 7.8 percent of the ERU (fig. 46), patch density increased from 4.5 to 8.9 patches per 10 000 ha (appendix 3), and mean patch size remained unchanged. Patch density of the moderate vulnerability class also increased from 17.7 to 22.8 patches per 10 000 ha, and mean patch size remained unchanged. Percentage of area in the low vulnerability class declined from 75.0 to 69.8 percent. Increased area in the high vulnerability class was associated primarily with increased area of Douglas-fir cover.

Area vulnerable to western pine beetle (type 1) disturbance of mature and old ponderosa pine declined (fig. 47); loss of area was observed in the moderate vulnerability class where percentage of area dropped from 18.8 to 16.5 percent of the ERU. As noted earlier, there was little appreciable loss of area in the ponderosa pine cover type, but area of old multistory and old single-story structures declined, as did area of understory reinitiation and stem-exclusion open canopy structures (appendix 2). Decline in area vulnerable to western pine beetle (type 1) was apparently associated with declining abundance of medium and large ponderosa pine in overstories associated with understory reinitiation, stem-exclusion open canopy, and old single-story and multistory forest structures (tables 20 and 21). Patch density of the moderate vulnerability class also increased from 11.3 to 15.2 patches per 10 000 ha, and mean patch size dropped from 304.5 to 128.5 ha (ns), indicating declining connectivity of host types. Declining connectivity of the ponderosa pine cover type also was observed (appendix 2).

Modeling rules for western pine beetle (type 2) and mountain pine beetle (type 2) patch vulnerabilities were identical, and results of change analyses were likewise identical. Here and following,

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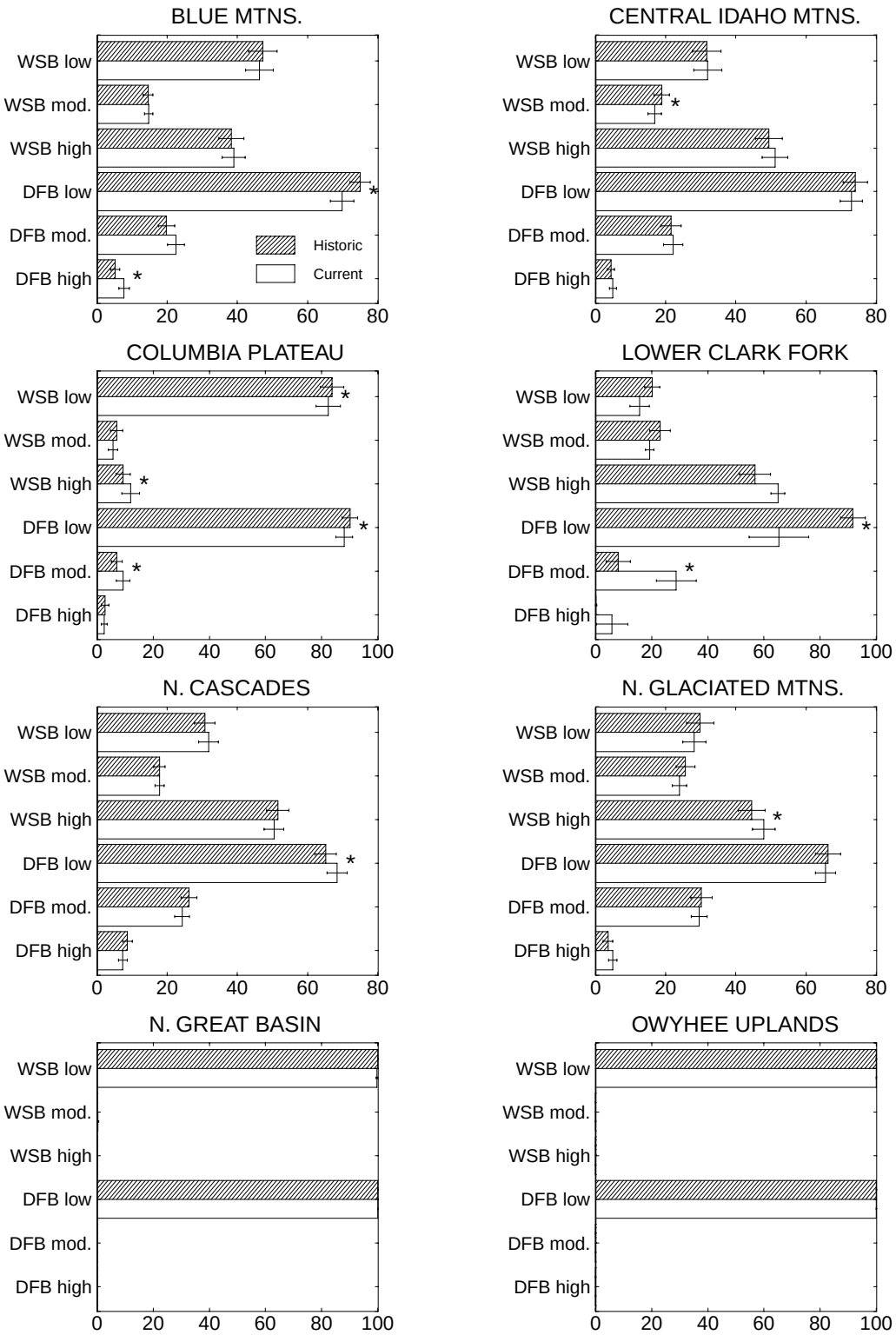
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N. GLACIATED MTNS.
N. GREAT BASIN
OWYHEE UPLANDS
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WSB mod.
WSB high
DFB low
DFB mod.
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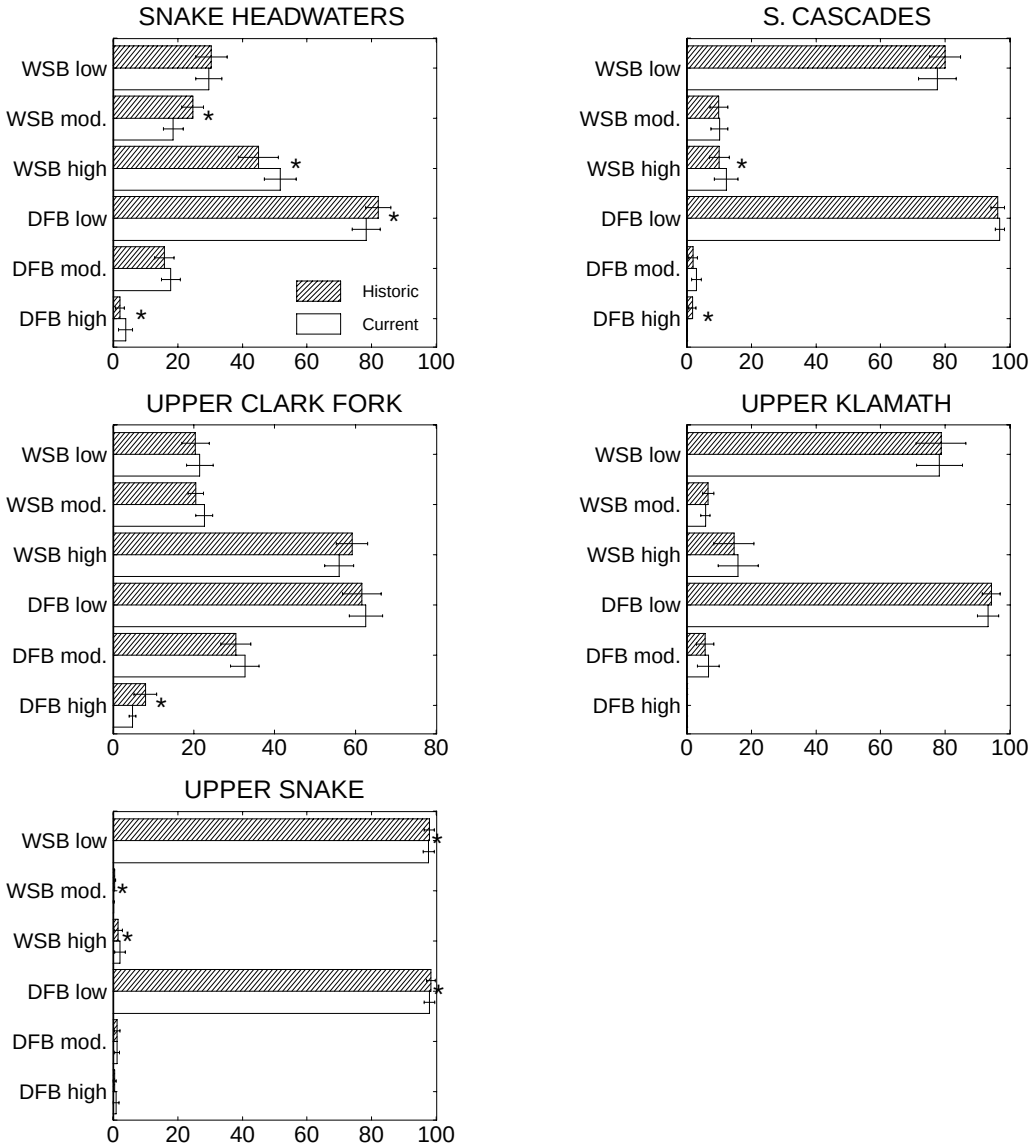
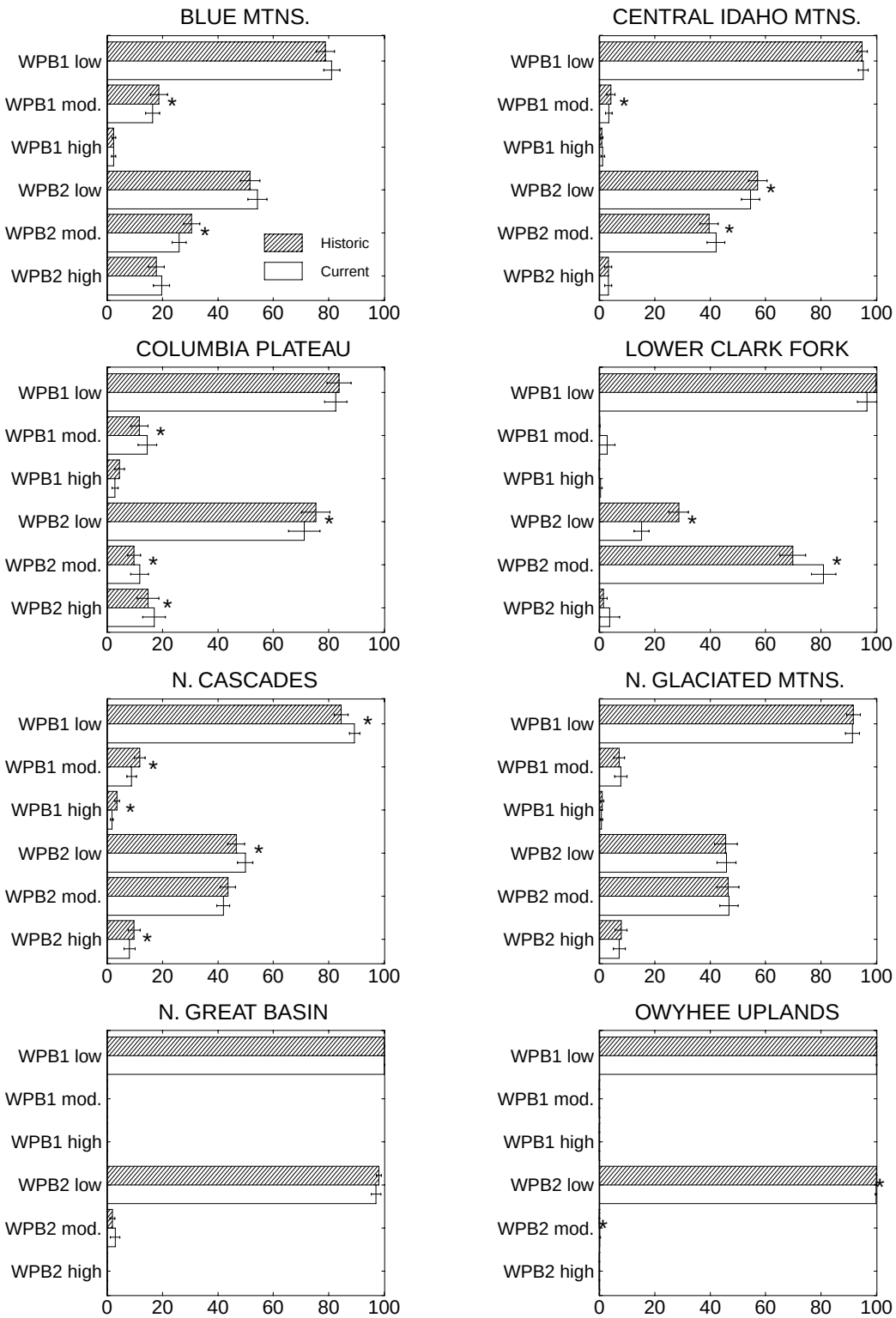


Figure 46—Historical and current distribution of western spruce budworm and Douglas-fir beetle disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Insect disturbance abbreviations are WSB = western spruce budworm and DFB = Douglas-fir beetle. Vulnerability class codes are low, moderate, and high.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N. GLACIATED MTNS.
N. GREAT BASIN
OWYHEE UPLANDS
WPB1 low
WPB1 mod.
WPB1 high
WPB2 low
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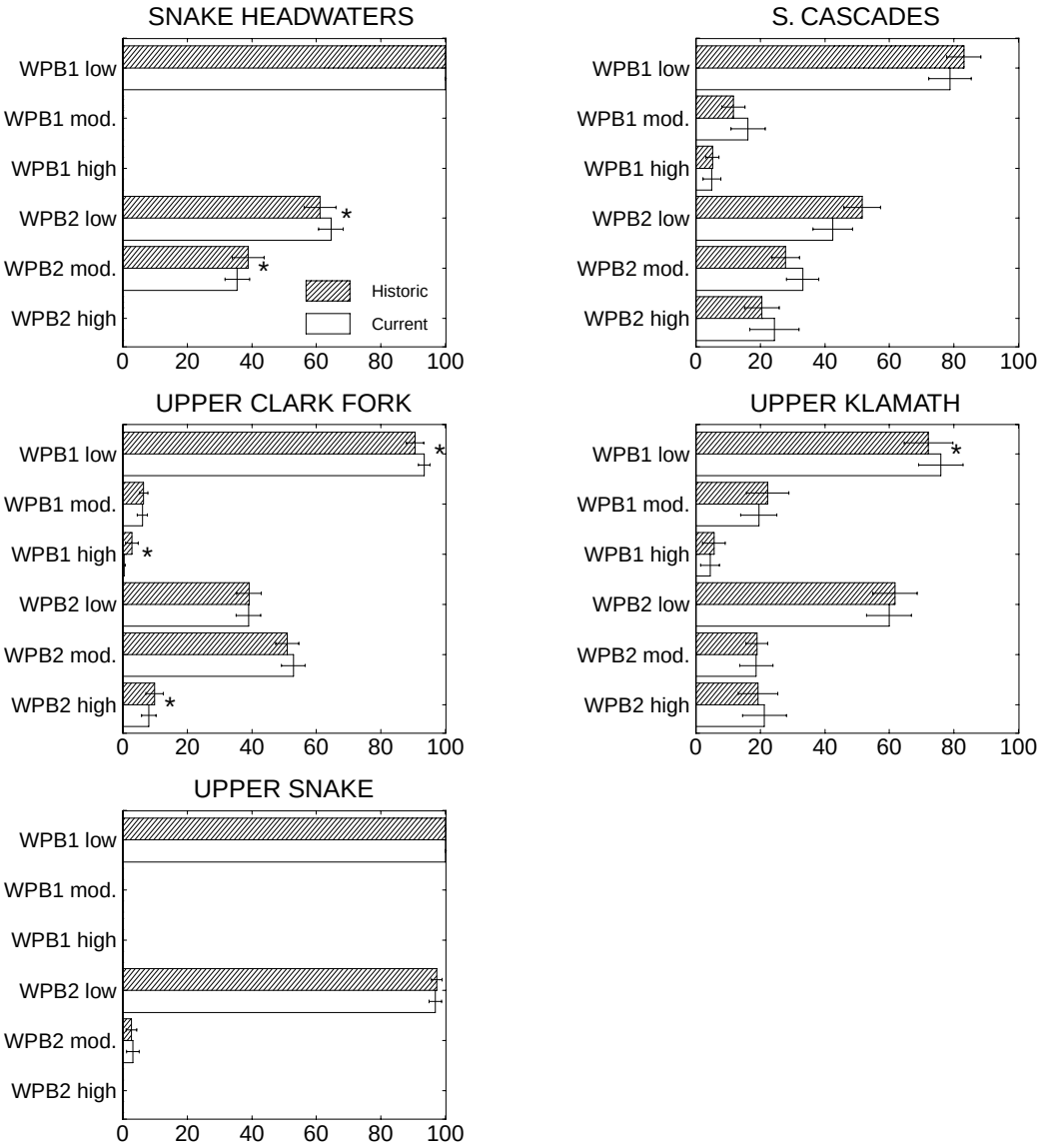

Figure 47—Historical and current distribution of western pine beetle type-1 and type-2 disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Insect disturbance abbreviations are WPB1=western pine beetle (type 1) of mature and old ponderosa pine, and WPB2=western pine beetle (type 2) of immature and high density ponderosa pine. Vulnerability class codes are low, moderate, and high.

we report them together. Percentage of area highly vulnerable to western pine beetle (type 2) and mountain pine beetle (type 2) disturbance of immature, high-density ponderosa pine remained unchanged during the sample period (figs. 47 and 48). Patch density increased from 10.5 to 13.7 patches per 10 000 ha, and mean patch size increased from 166.9 to 254.5 ha. These results, and results from analysis of change in forest cover types and structural classes indicated that young and middle-aged patches vulnerable to this disturbance were only slightly more numerous in the current vegetation condition than in the historical condition, but the average size of highly vulnerable patches had increased by 52 percent. Conversely, area and connectivity of the moderate vulnerability class declined; percentage of area fell from 30.6 to 26.0 percent of the ERU, patch density rose by 30 percent from 20.6 to 26.7 patches per 10 000 ha, and mean patch size declined by 45 percent from 259.7 to 141.8 ha.

Another significant change in area vulnerable to bark beetle disturbance was associated with mountain pine beetle (type 1) disturbance of high density lodgepole pine. Percentage of area in the high vulnerability class fell from 6.7 to 5.1 percent, a 24-percent loss of vulnerable area during the sample period (fig. 48). Because no significant change in area of the lodgepole pine cover type was observed where lodgepole pine was the principal cover species (appendix 2), these results suggest that the percentage of area of lodgepole pine in mixed species cover types declined during the sample period. As modeled, both pure and mixed species cover types with lodgepole pine were host types (see Hessburg and others, in press).

Area and connectivity of the fir engraver high vulnerability class declined (fig. 49); change was correlated with observed declines in grand fir-white fir and subalpine fir-Engelmann spruce cover type area (appendix 2). Percentage of area in the high vulnerability class fell from 24.6 to 15.0 percent, patch density rose from 9.0 to 12.4 patches per 10 000 ha, and mean patch size declined by 67 percent from 428.3 to 142.2 ha (appendix 3). Percentage of area in low and moderate vulnerability rose from 65.0 to 70.4 percent and from 10.3 to 14.6 percent of the ERU, respectively. Mean patch size of low vulnerability areas declined from 1907.4 to 1409.0 ha, and mean patch size of moderate vulnerability areas rose from 65.3 to 81.4 ha, indicating that areas of fir engraver host and nonhost type are more highly fragmented in the current condition.

Finally, area and connectivity of the spruce beetle high vulnerability class declined (fig. 49); change was correlated with observed declines in subalpine fir-Engelmann spruce cover type area (appendix 2). Percentage of area in the high vulnerability class fell from 2.6 to 0.7 percent of the ERU, and percentage of area in the low vulnerability class rose from 63.3 to 66.0 percent. Observations of Gast and others (1991) suggest that declining vulnerability to spruce beetle in the Blue Mountains ERU was associated with spruce beetle outbreaks of the last decade that already have claimed many old Engelmann spruce patches observed in the historical vegetation coverage.

Pathogen disturbance vulnerabilities— *Dwarf mistletoes*—Area and connectivity of patches vulnerable to Douglas-fir dwarf mistletoe disturbance increased (fig. 50). Percentage of area rose sharply by 63 percent from 10.1 to 16.5 percent, patch density more than doubled from 9.3 to 19.6 patches per 10 000 ha, and mean patch size rose by 44 percent from 87.5 to 125.7 ha (appendix 3). Increased area in the high vulnerability class was associated with expanded area of the Douglas-fir cover type, increased canopy layering, and contiguity of host patches apparently brought about by fire exclusion and selective harvesting.

Area and connectivity of patches vulnerable to western (ponderosa pine) dwarf mistletoe disturbance declined (fig. 51). Percentage of area fell from 10.4 to 8.1 percent of the ERU, patch density rose from 9.6 to 12.7 patches per 10 000 ha, and mean patch size remained unchanged. Because no significant change in area of the ponderosa pine cover type was observed where ponderosa pine was the principal cover species (appendix 2), these results suggest that patch area of ponderosa pine in mixed species cover types with multilayered canopies declined significantly during the sample period.

Connectivity of patches vulnerable to western larch dwarf mistletoe disturbance declined (appendix 3); patch density rose from 1.8 to 3.6 patches per 10 000 ha, and mean patch size declined from 16.0 to 9.8 ha. Area in the low vulnerability class increased from 95.9 to 96.5 percent.

Root diseases—Area and connectivity of patches vulnerable to laminated root rot disturbance increased during the sample period, but the observed change in area was not significant at $P \leq 0.2$ (fig. 52). Percentage of area rose from 34.5 to 37.0 percent (ns), and mean patch size increased from 376.7 to 572.4 ha (appendix 3), indicating increased contiguity of susceptible host patches. The observed increase in vulnerability was primarily associated with increased area of the Douglas-fir cover type, which rose from 7.7 to 17.1 percent of the ERU area (appendix 2).

Area and connectivity of patches vulnerable to S-group annosum disturbance declined (fig. 53). Percentage of area declined from 24.3 to 16.9 percent of the ERU, patch density increased from 11.0 to 15.0 patches per 10 000 ha, and mean patch size declined by 52 percent from 238.3 to 114.7 ha (appendix 3). The apparent change in vulnerability of Blue Mountains landscapes to S-group annosum was associated with observed declines in area of grand fir-white fir, and subalpine fir-Engelmann spruce cover types, where these species represented the principal overstory cover (appendix 2). But the story of change is perhaps more complex than these results suggest. Although it is apparent that a dramatic reduction in dominance of overstory true firs has occurred, grand fir, white fir, and subalpine fir have significantly increased in area where they occur as primary understory species occupying lower and intermediate crown classes (see also Lehmkuhl and others 1994). Because spores of this pathogen readily infect freshly cut stumps, and because the majority of stands with true fir understories have experienced timber harvest, we suggest that expression of S-group annosum root disease disturbance in the foreseeable future will be far greater than that occurring in our photo-interpreted historical or current condition.

Connectivity of area vulnerable to P-group annosum also declined (fig. 53); patch density remained relatively stable, and mean patch size declined from 110.7 to 75.2 ha. The observed decline in connectivity was associated with reduced connectivity of patches with medium and large ponderosa pine in pure and mixed compositions (table 21 and appendix 2).

Area vulnerable to tomentosus root and butt rot disturbance declined, but we suggest that the change is temporary and superficial; percentage of area fell from 4.4 to 2.5 percent of the ERU (fig. 54). Spruce beetle outbreaks during the 1980s resulted in mortality of many old patches of Engelmann spruce (Gast and others 1991). With increasing age and declining vitality, remaining patches of mature and old spruce with tomentosus (and other) root diseases eventually will experience a period of heightened gap disturbance where trees collapse and are windthrown as a consequence of a resident root pathogen and strong winds. Windthrown trees usually are infested by the spruce beetle. As patches subsequently regenerate, many again will be comprised of Engelmann spruce in pure and mixed compositions, and tomentosus root disease inoculum already will be resident in the patch.

Area and connectivity of patches vulnerable to Schweinitzii root and butt rot disturbance increased during the sample period (fig. 54); percentage of area in the high vulnerability class rose from 46.7 to 52.1 percent of the ERU, patch density dropped from 12.7 to 10.5 patches per 10 000 ha, and mean patch size increased by 149.1 ha from 807.1 ha (ns). The observed increase in vulnerability was associated primarily with increased cover and contiguity of Douglas-fir (appendix 2). Percentage of area in the moderate vulnerability class declined by a corresponding amount.

Central Idaho Mountains ERU—Subbasins sampled within the Central Idaho Mountains ERU (figs. 11, 14, 17, 18, and 22) included the Boise-Mores (BOM), Big Wood (BWD), Lemhi (LMH), Lochsa (LOC), Medicine Lodge (MDL), South Fork Clearwater (SFC), South Fork Salmon (SFS), and Upper Middle Fork Salmon (UMS). Among these subbasins, 43 historical and current subwatershed pairs were sampled.

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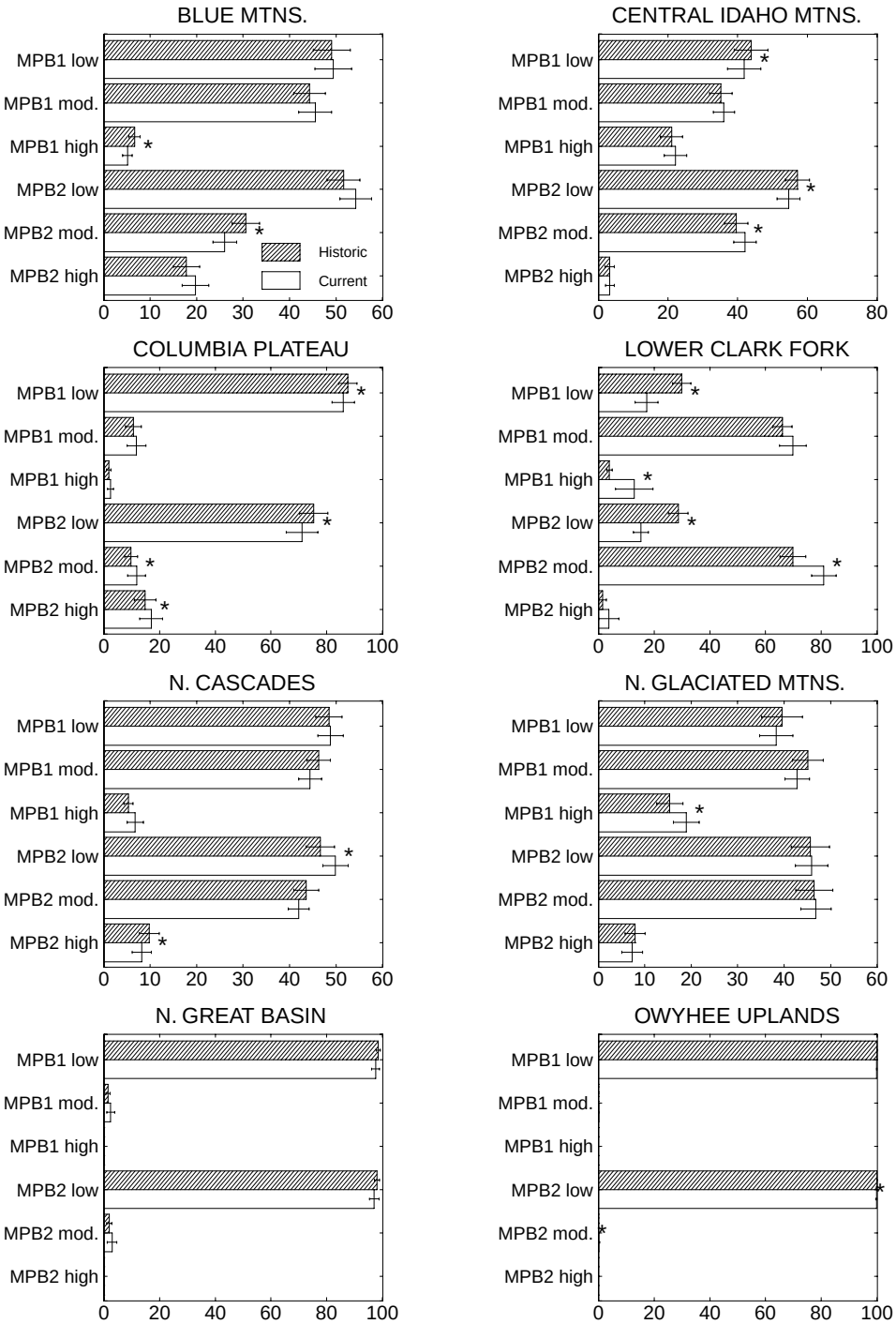
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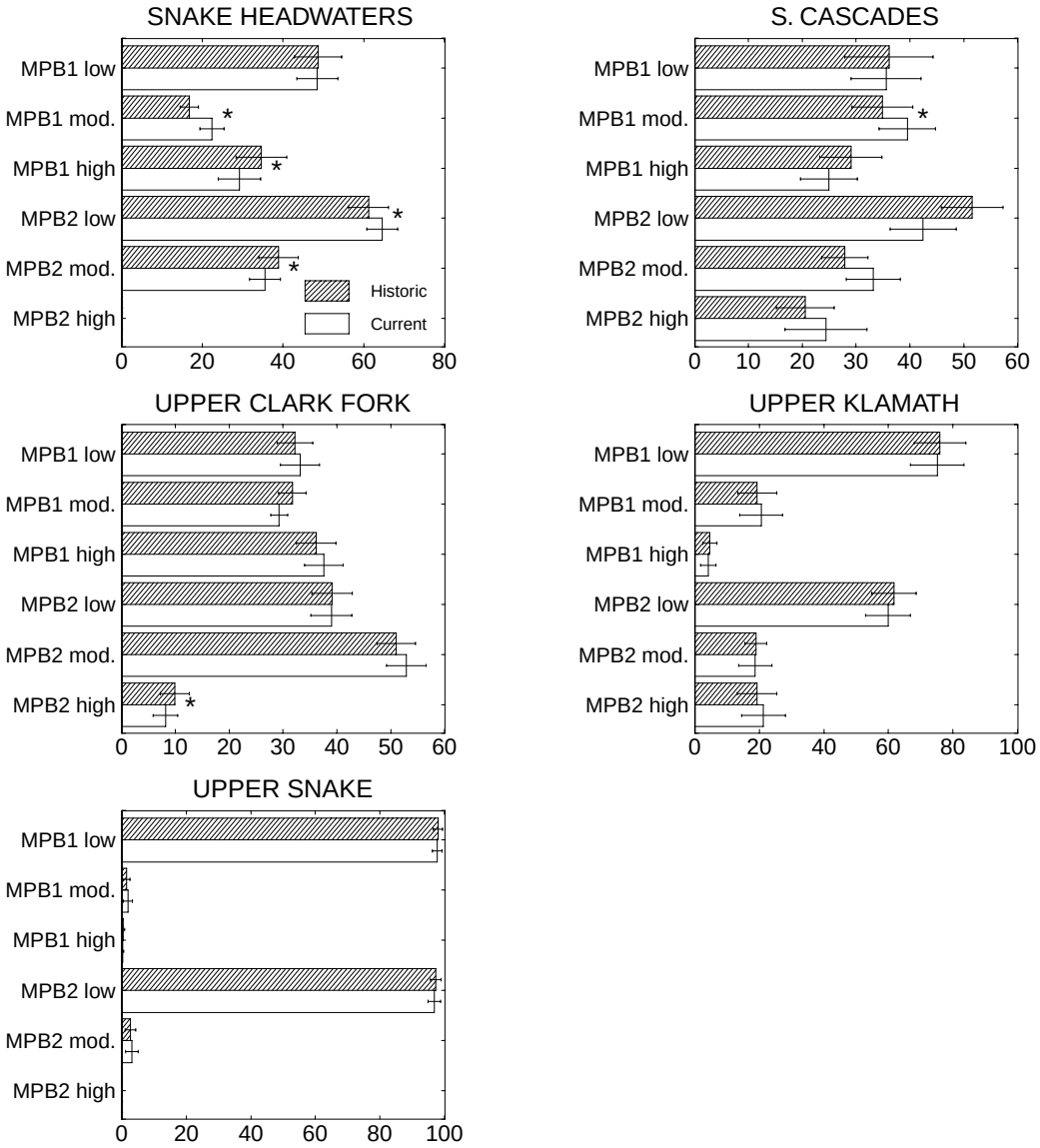
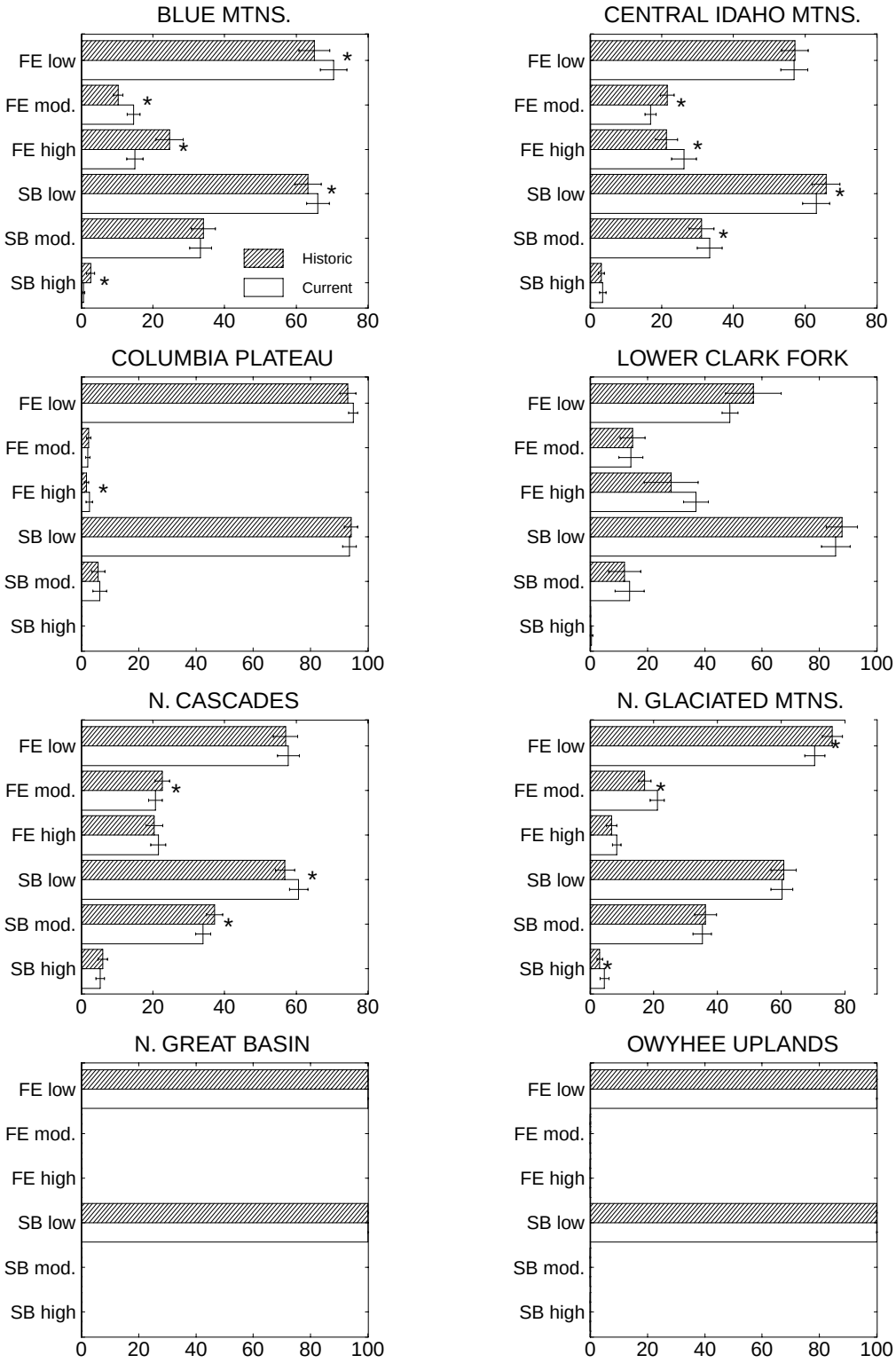


Figure 48—Historical and current distribution of mountain pine beetle type-1 and type-2 disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Insect disturbance abbreviations are MPB1=mountain pine beetle (type 1) of high-density lodgepole pine, and MPB2=mountain pine beetle (type 2) of immature and high-density ponderosa pine. Vulnerability class codes are low, moderate, and high.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SB low
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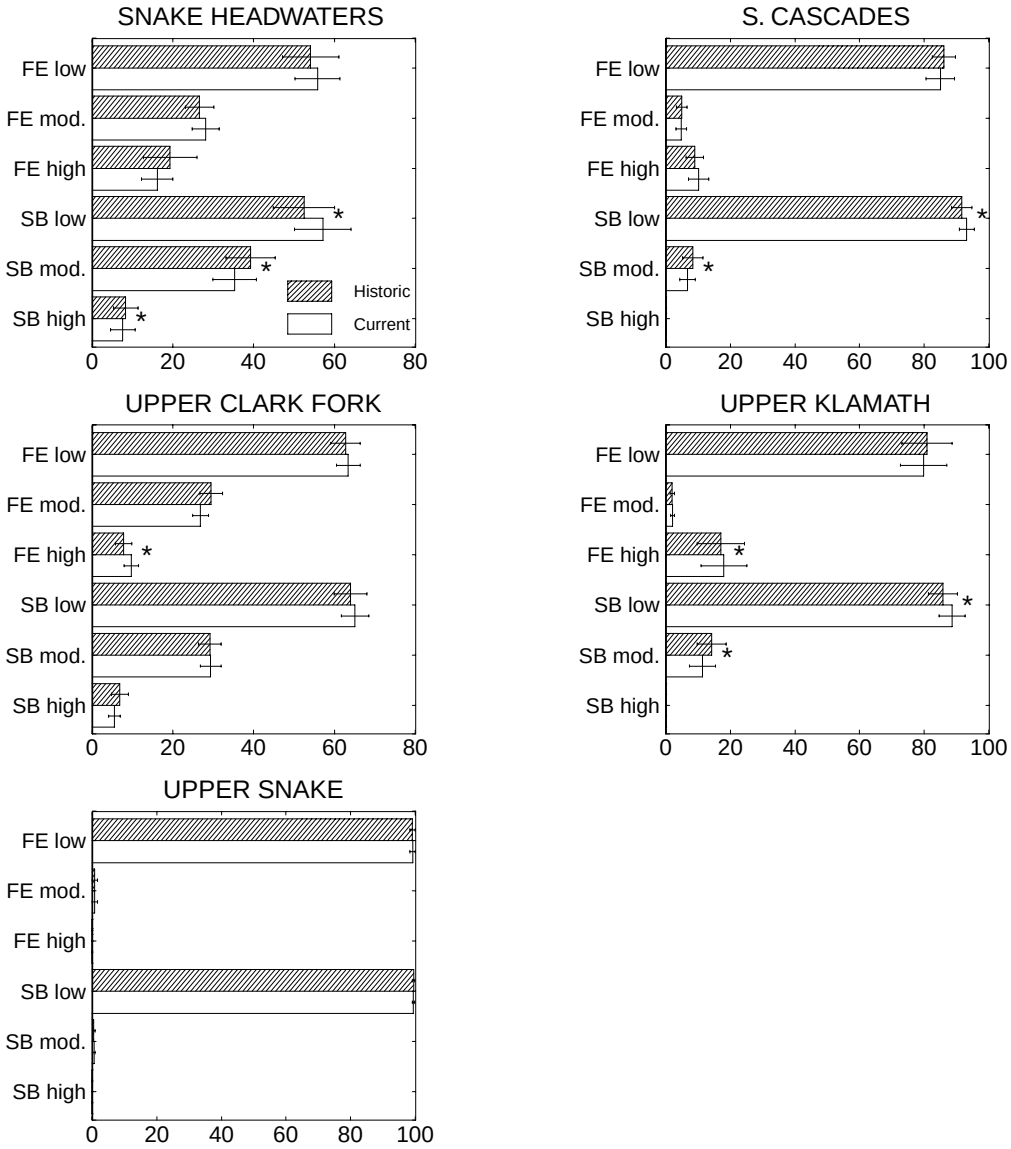
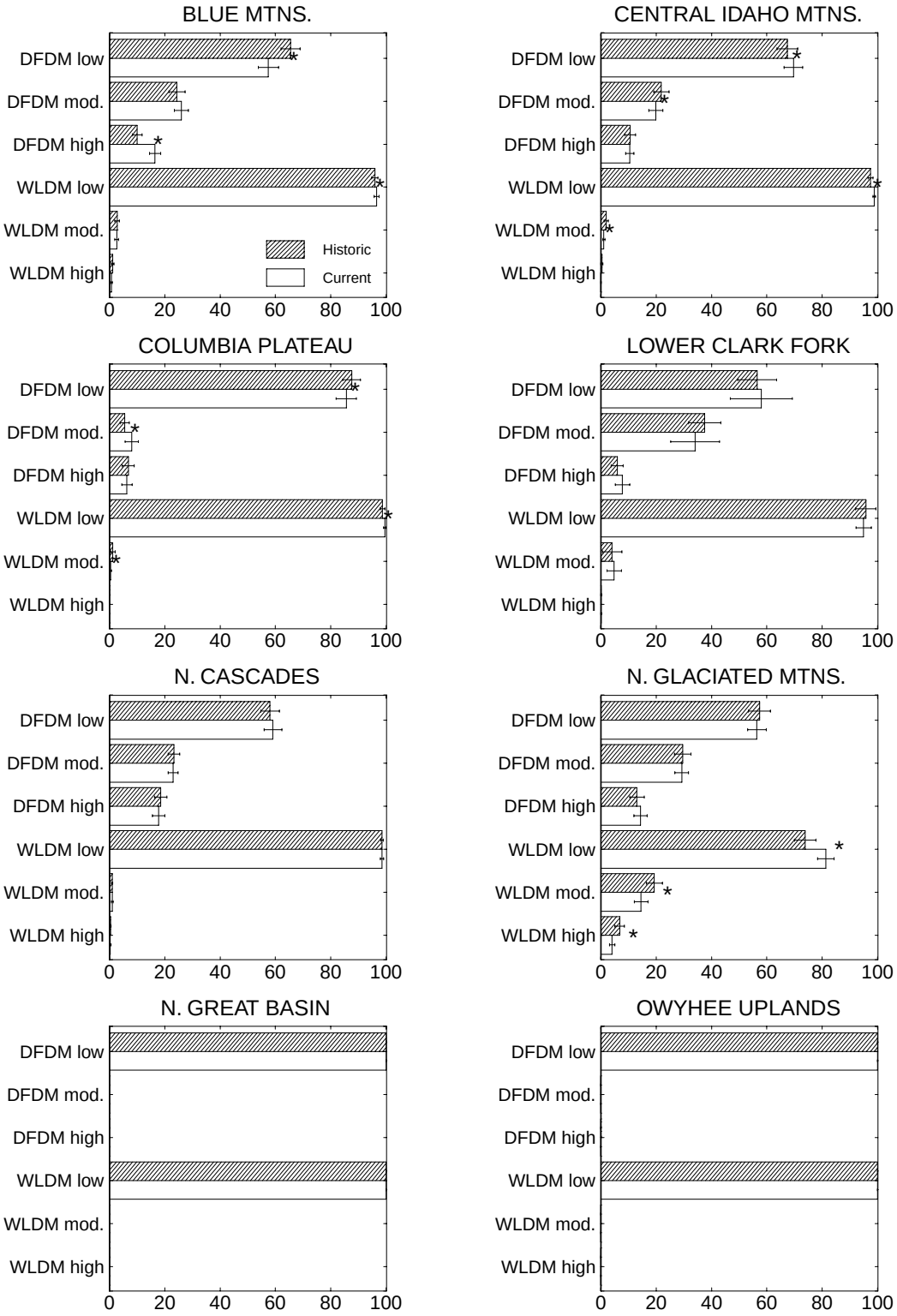


Figure 49—Historical and current distribution of fir engraver and spruce beetle disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Insect disturbance abbreviations are FE = fir engraver and SB = spruce beetle. Vulnerability class codes are low, moderate, and high.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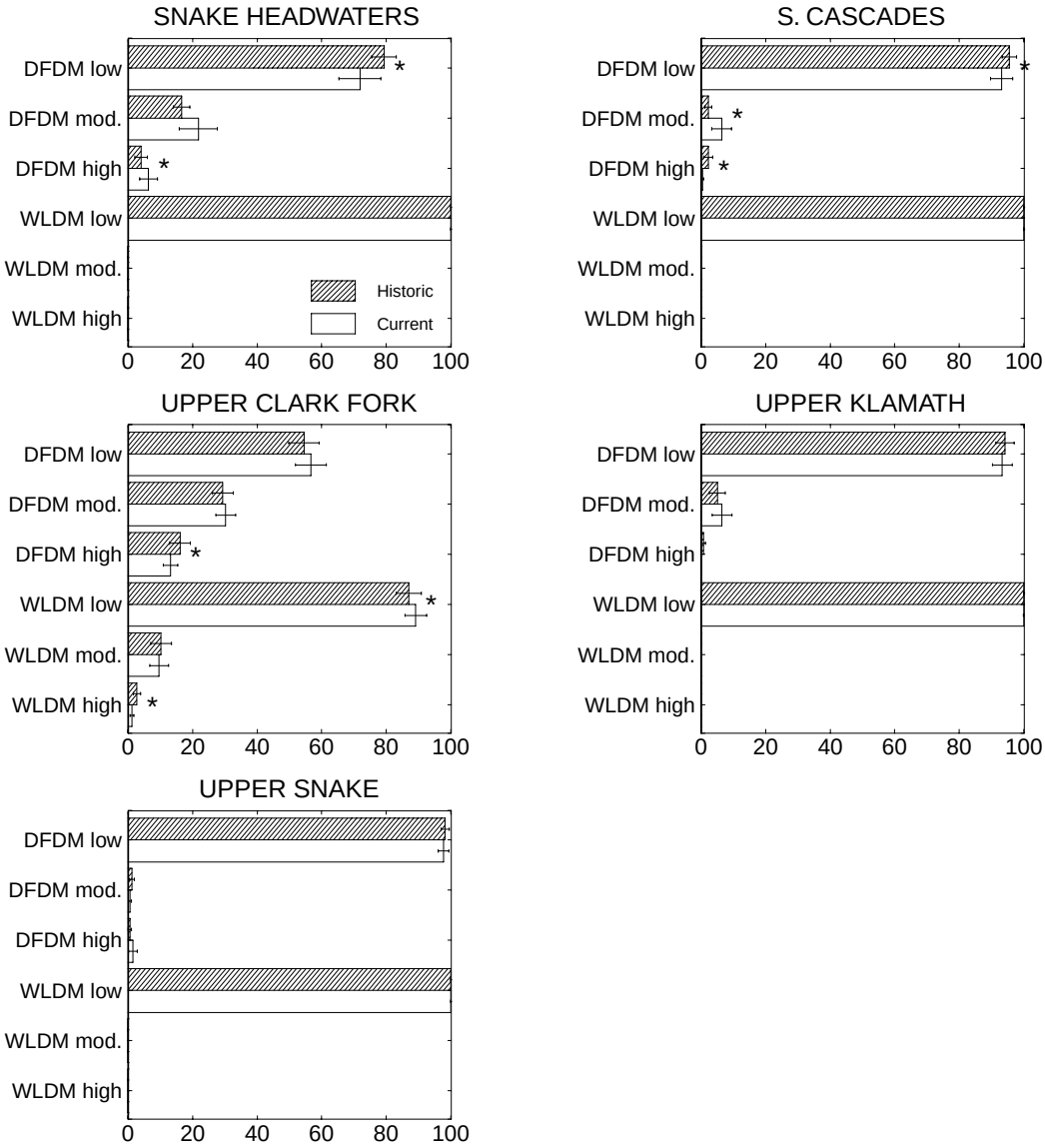
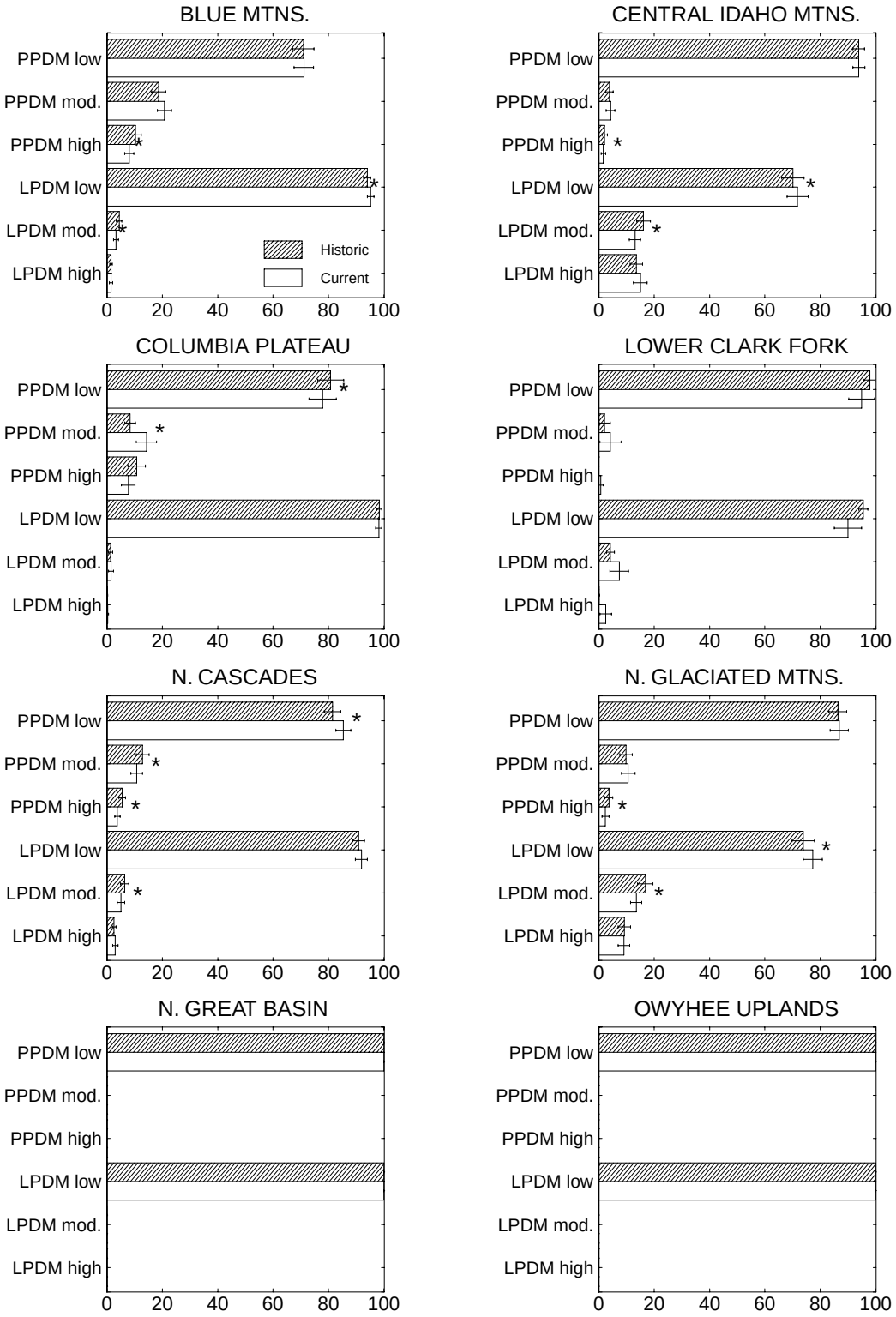


Figure 50—Historical and current distribution of Douglas-fir and western larch dwarf mistletoe disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Pathogen disturbance abbreviations are DFDM = Douglas-fir dwarf mistletoe and WLDM = western larch dwarf mistletoe. Vulnerability class codes are low, moderate, and high.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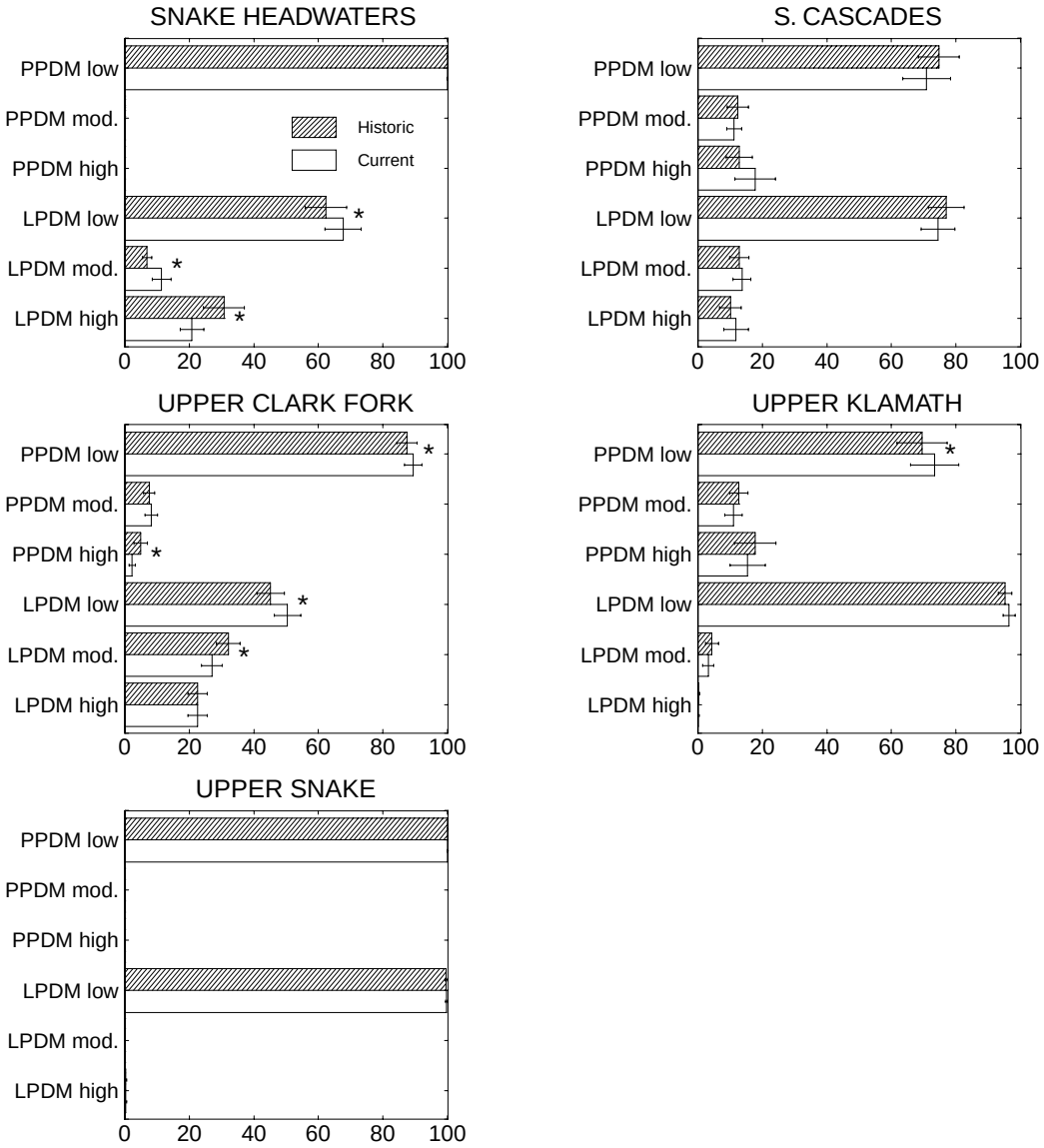
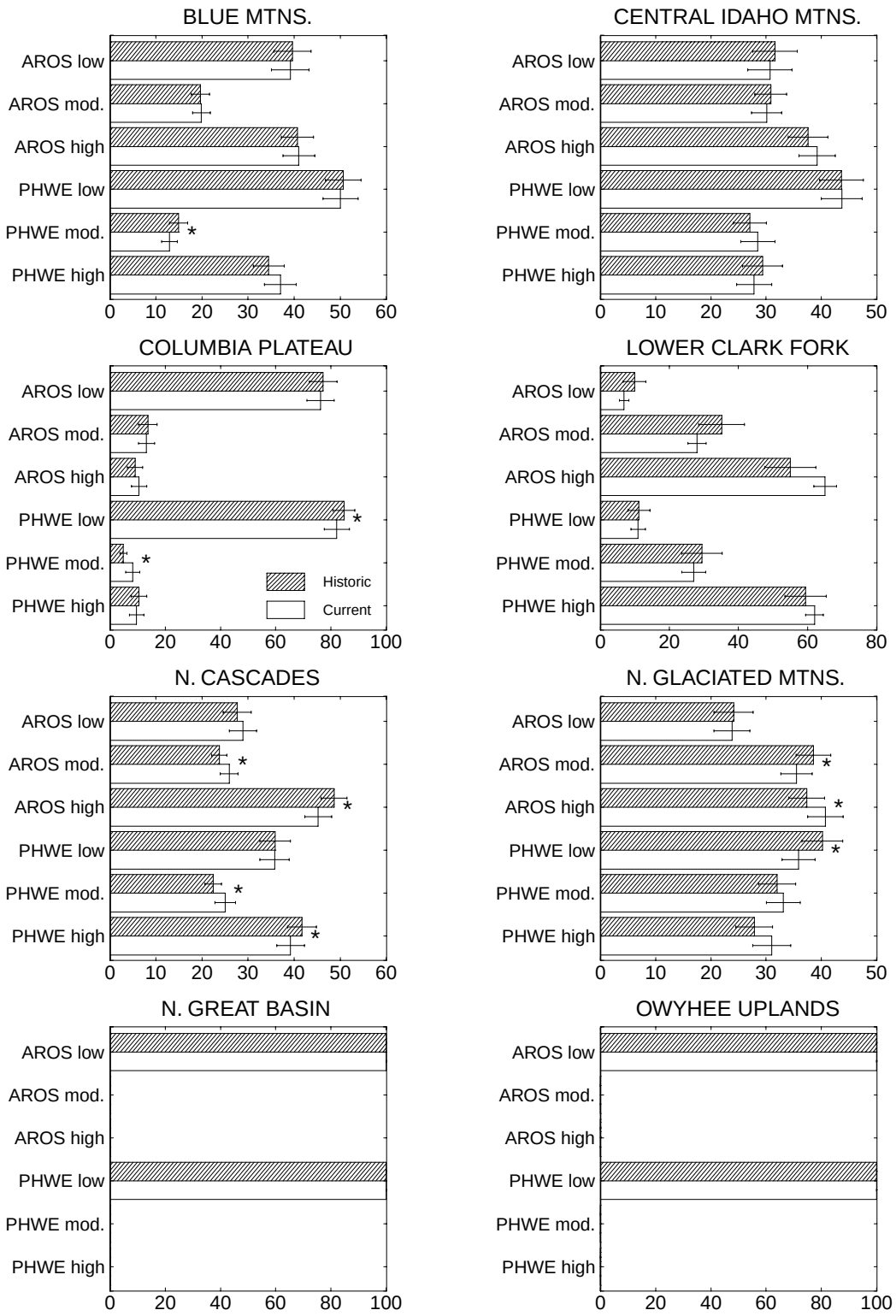


Figure 51—Historical and current distribution of ponderosa pine and lodgepole pine dwarf mistletoe disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Pathogen disturbance abbreviations are PPDM = ponderosa pine dwarf mistletoe and LPDM = lodgepole pine dwarf mistletoe. Vulnerability class codes are low, moderate, and high.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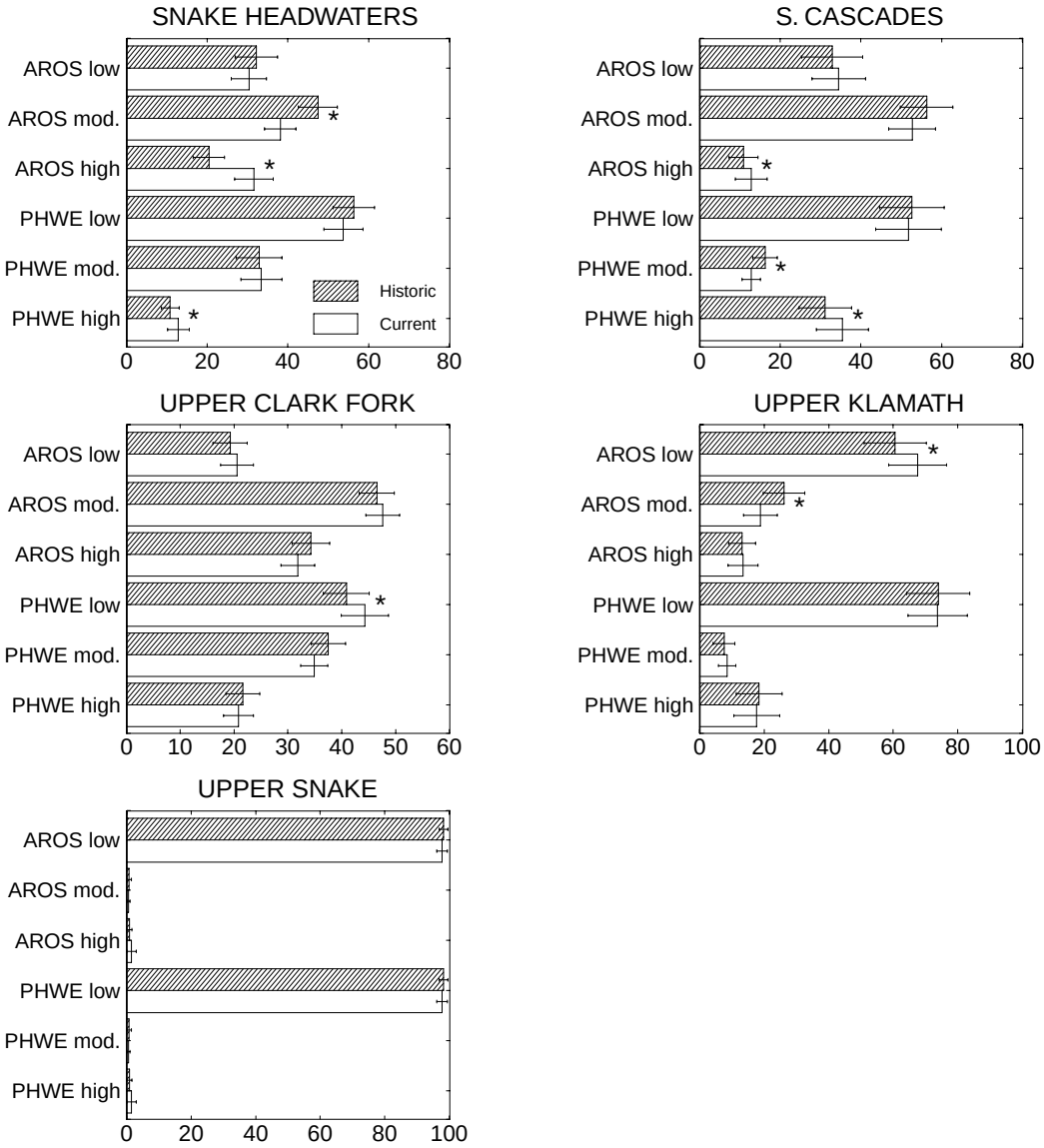
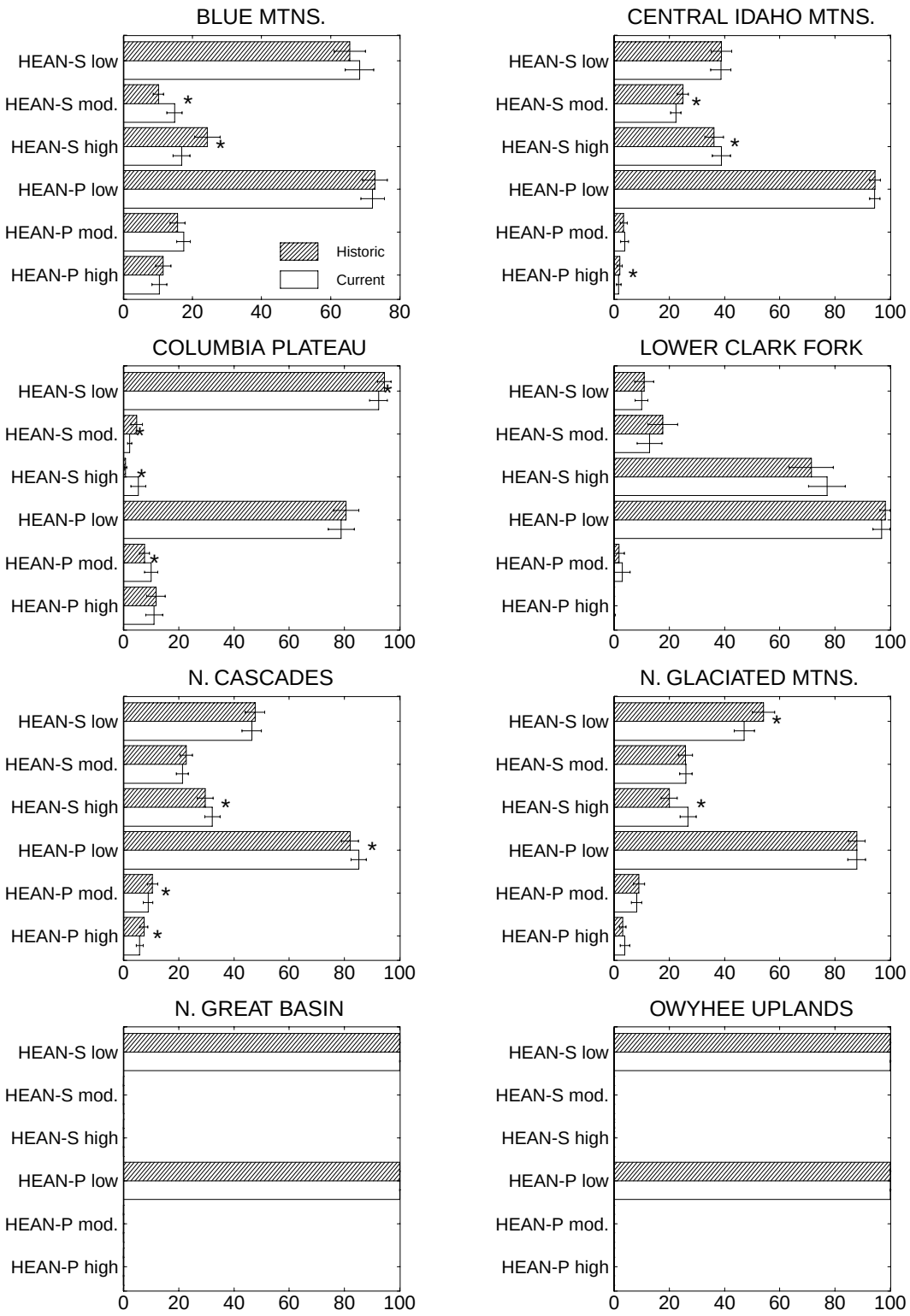


Figure 52—Historical and current distribution of *Armillaria* root disease and laminated root rot disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Pathogen disturbance abbreviations are AROS = *Armillaria* root disease and PHWE = laminated root rot. Vulnerability class codes are low, moderate, and high.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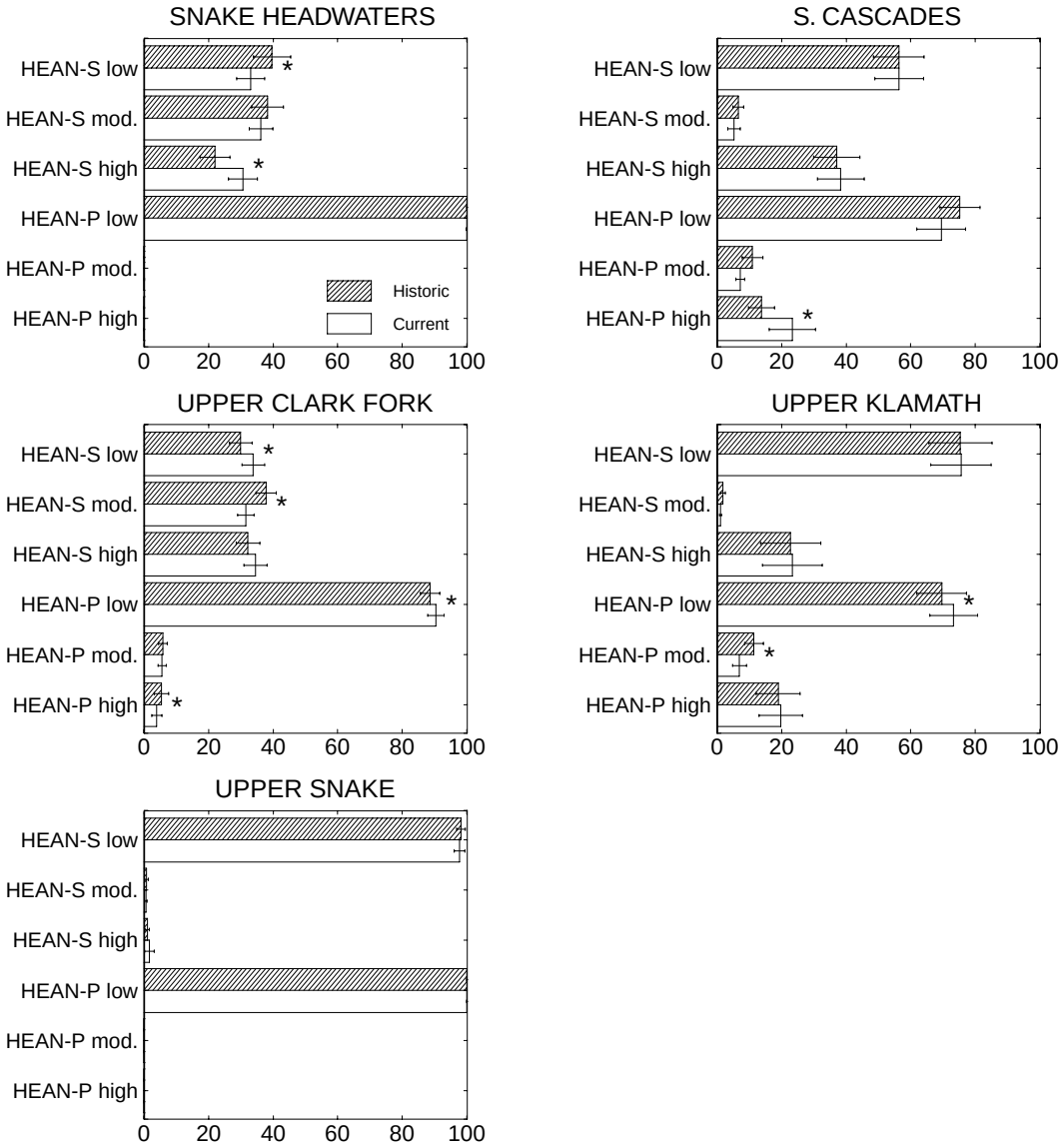
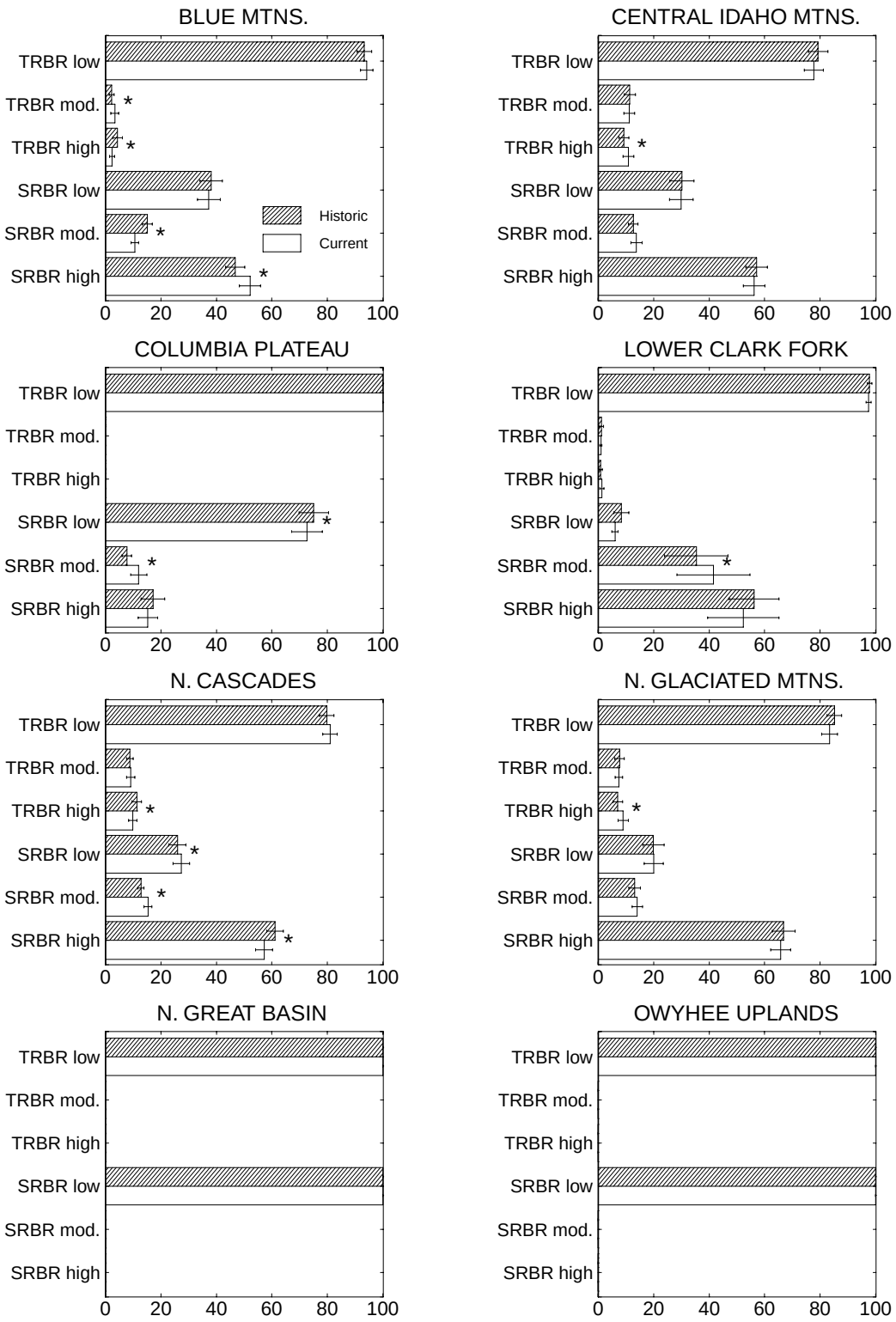


Figure 53—Historical and current distribution of S- and P-group annosum root disease disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Pathogen disturbance abbreviations are HEAN-S = S-group annosum root disease and HEAN-P = P-group annosum root disease. Vulnerability class codes are low, moderate, and high.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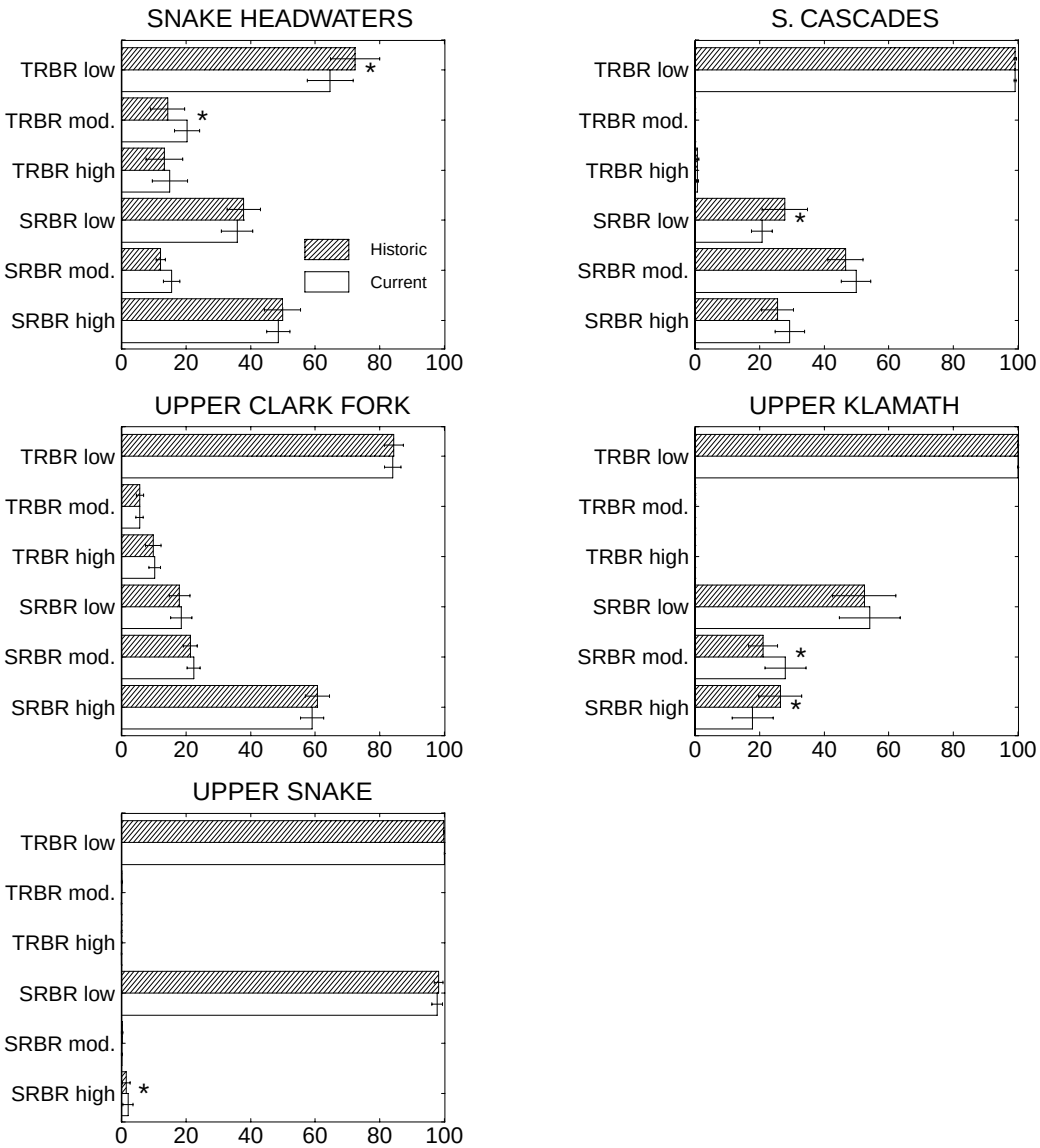


Figure 54—Historical and current distribution of tomentosus and Schweinitzii root and butt rot disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Pathogen disturbance abbreviations are TRBR = tomentosus root and butt rot and SRBR = Schweinitzii root and butt rot. Vulnerability class codes are low, moderate, and high.

Insect disturbance vulnerabilities—
Defoliators—There were no statistically significant changes in percentage of area or connectivity of patches vulnerable to western spruce budworm disturbance at this reporting scale (appendix 3). Percentage of area in the high vulnerability class rose from 49.4 to 51.1 percent (ns), and area in the moderate vulnerability class declined from 18.9 to 16.9 percent (fig. 46).

Bark beetles—Percentage of area vulnerable to western pine beetle (type 1) disturbance of mature and old ponderosa pine remained relatively constant during the sample period, but connectivity of vulnerable patches declined significantly owing to the relatively limited area of the ponderosa pine cover type. Patch density of the high vulnerability class rose from 1.6 to 2.8 patches per 10 000 ha, and mean patch size remained unchanged. Mean patch size of the moderate vulnerability class declined from an average of 34.3 to 20.1 ha.

Patch area vulnerable to the fir engraver disturbance increased during the sample period (fig. 49); percentage of area in the high vulnerability class rose from 21.3 to 26.2 percent of the ERU, and area in the moderate vulnerability class declined by a corresponding amount (appendix 3). Connectivity of patches vulnerable to fir engraver disturbance increased; patch density remained stable, and mean patch size rose from 156.7 to 254.6 ha. Enhanced connectivity of vulnerable patches was associated with increased patch size and contiguity of subalpine fir patches (appendix 2).

Pathogen disturbance vulnerabilities—
Dwarf mistletoes—Area and connectivity of patches vulnerable to western dwarf mistletoe disturbance declined during the sample period (fig. 51); percentage of area fell from an average of 2.2 to 1.8 percent of the ERU, and mean patch size declined from 17.2 to 11.4 ha (appendix 3). Because no significant change in area of the ponderosa pine cover type was observed where ponderosa pine was the principal cover species, these results suggest that area of ponderosa pine in mixed species cover types with multilayered canopies declined during the sample period.

Root diseases—Connectivity of patches vulnerable to laminated root rot disturbance declined (appendix 3); patch density in the high vulnerability class rose by 33 percent, from 14.5 to 19.3 patches per 10 000 ha, and mean patch size declined from 321.5 to 253.2 ha. Reduced connectivity of vulnerable patches was associated with declining connectivity of host cover.

Area vulnerable to S-group annosum root disease disturbance increased; percentage of area in the high vulnerability class rose from an average of 36.2 to 38.9 percent of the ERU (fig. 53), and area in the moderate vulnerability class declined by a corresponding amount. Increase in vulnerable area was associated with expanding grand fir, Douglas-fir, subalpine fir-Engelmann spruce, and western hemlock-western redcedar cover type area (appendix 2) and increased area with visible logging entry (table 27). In contrast, area and connectivity of patches vulnerable to P-group annosum root disease disturbance declined during the sample period (fig. 53); percentage of area fell from an average of 2.1 to 1.7 percent, and mean patch size declined from 15.0 to 12.4 ha. As noted earlier, because no significant change in ponderosa pine-dominated cover was observed, these results suggest that area of ponderosa pine in mixed species cover types declined significantly during the sample period.

Area and connectivity of patches vulnerable to tomentosus root disease disturbance increased (fig. 54). Percentage of area in the high vulnerability class increased by 18 percent, rising from an average of 9.3 to 11.0 percent of the ERU, thereby indicating that area comprised of medium and large Engelmann spruce increased during the sample period. Patch density rose from 12.4 to 15.0 patches per 10 000 ha, and mean patch size remained stable.

Columbia Plateau ERU—Subbasins sampled within the Columbia Plateau ERU (figs. 9, 10, 12, and 15) included the Lower Crooked (LCR), Lower John Day (LJD), Lower Yakima (LYK), Palouse (PLS), and Upper Yakima (UYK). Among these subbasins, 38 historical and current subwatershed pairs were sampled.

Insect disturbance vulnerabilities—
Defoliators—Area vulnerable to western spruce budworm disturbance increased during the sample period (fig. 46). Percentage of area in the high vulnerability class increased by 29 percent, rising from an average of 9.3 to 12.0 percent of the ERU. In the Columbia Plateau, forests comprise less than one-third of the area (appendix 2). In the historical condition, 36 percent of the forested area was classified as high vulnerability area, and in the current condition, 41 percent was classified as high vulnerability (appendix 3). Cover type changes alone did not account for the observed increase in vulnerability; increased vulnerability was associated with increased area of Douglas-fir cover in pure and mixed types (appendix 2) and increased area of Douglas-fir and grand fir in multilayered understories.

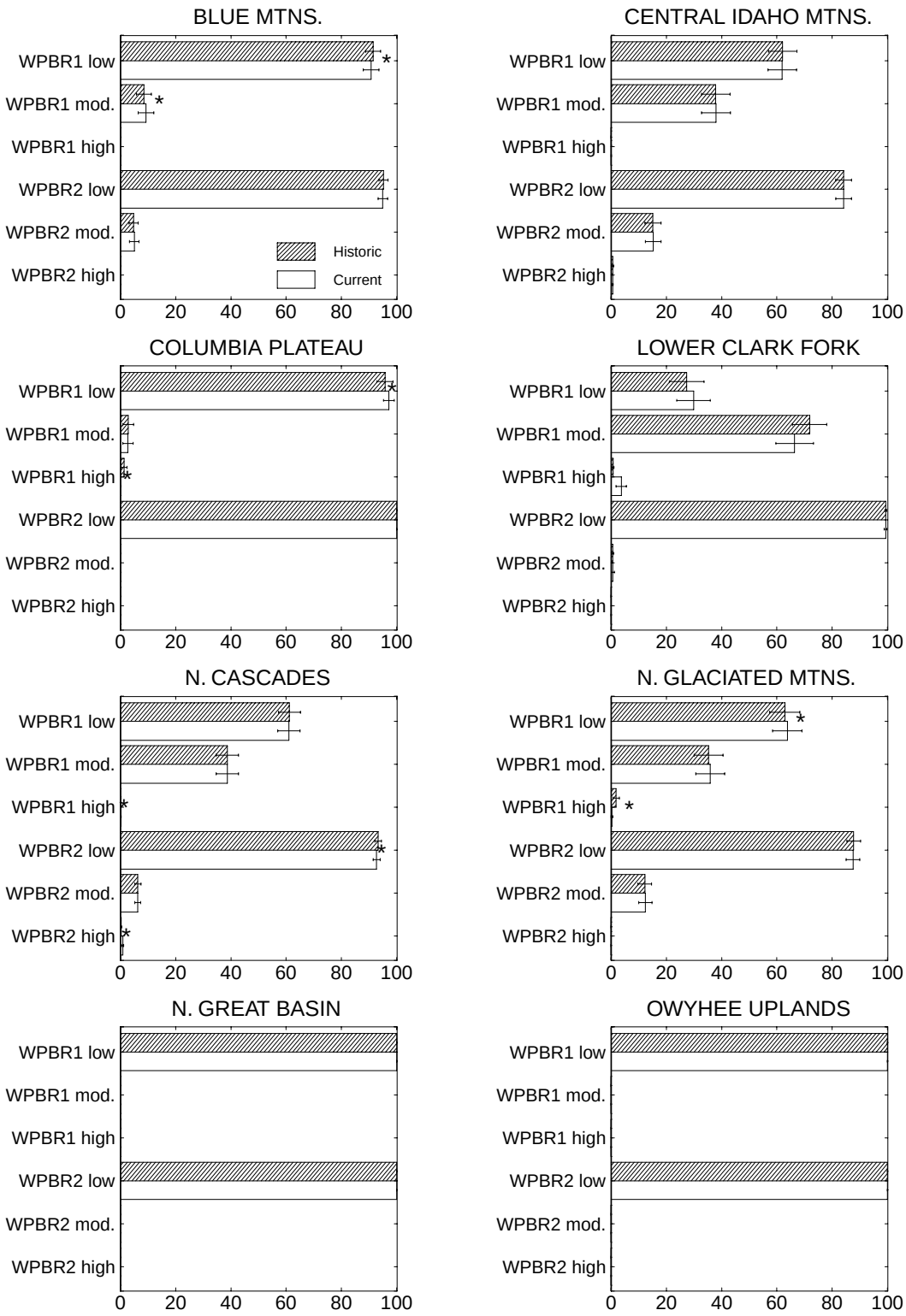
Bark beetles—Area vulnerable to western pine beetle (type 1) disturbance of mature and old ponderosa pine declined (fig. 47), but the change was not significant at $P \leq 0.2$. Percentage of area in the high vulnerability class fell from an average of 4.6 to 2.9 percent of the ERU (ns). Connectivity of area in the high vulnerability class declined significantly; mean patch size declined by 48 percent, dropping from an average of 50.8 to 26.6 ha. Area in the ponderosa pine cover type actually increased during the sample period, rising from 19.2 to 21.4 percent, but area in old multistory and old single-story structures declined (appendix 2). These results suggest that contiguity of patches with medium and large ponderosa pine in mixed species overstories declined (tables 20 and 21). (Note that large tree structure was potentially associated with all classified forest structures; see also table 6.) Because total area in old forest structures declined by 1.1 percent (appendix 2), some of the loss in connectivity of the high vulnerability class was associated with reduced abundance of scattered medium and large ponderosa pine in structural classes other than old forest.

Area vulnerable to western pine beetle (type 2) and mountain pine beetle (type 2) disturbance of immature, high-density ponderosa pine increased during the sample period (figs. 47 and 48). Percentage of area in the high vulnerability class rose from an average of 14.9 to 17.1 percent of the ERU, and area in the moderate vulnerability class rose from 9.8 to 11.8 percent of the ERU. Increasing vulnerability was associated with expanded area of ponderosa pine cover in young and middle-aged structures (appendix 2).

Finally, area vulnerable to fir engraver disturbance increased (fig. 49); percentage of area in the high vulnerability class rose from 1.8 to 2.9 percent. Area where grand fir was the principal cover species actually declined by a small amount during the sample period (appendix 2), but area where grand fir occurred in mixed species cover types and as understory species cover increased as a probable result of fire exclusion and harvest of seral species.

Pathogen disturbance vulnerabilities—
Root diseases—Area and connectivity of patches vulnerable to S-group annosum root disease disturbance increased (fig. 53); percentage of area climbed sharply, nearly sevenfold, rising from an average of 0.8 to 5.4 percent of the ERU. Area in moderate and low vulnerability classes declined significantly by a corresponding amount. Patch density of high vulnerability areas rose from 1.3 to 2.2 patches per 10 000 ha, and mean patch size increased more than eightfold from 15.6 to 132.1 ha. Increase in area of host cover types alone did not account for the dramatic rise in vulnerable area. Our results indicated that area of grand fir and western hemlock in mixed species cover types and occurring as understory species increased during the sample period, as did area in these susceptible host types having visible logging entry.

Rusts—Area vulnerable to white pine blister rust (type 1) disturbance of western white pine declined (fig. 55 and appendix 3); percentage of area in the high vulnerability class plummeted by 93 percent, declining from an average of 1.4 to 0.1 percent of the ERU. In similar fashion, mean patch size declined from 45.6 to 4.3 ha, but the change was not significant at $P \leq 0.2$. The observed decline in high vulnerability area was likely the result of more than eight decades of blister rust mortality and selective harvest of western white pine early in the 20th century.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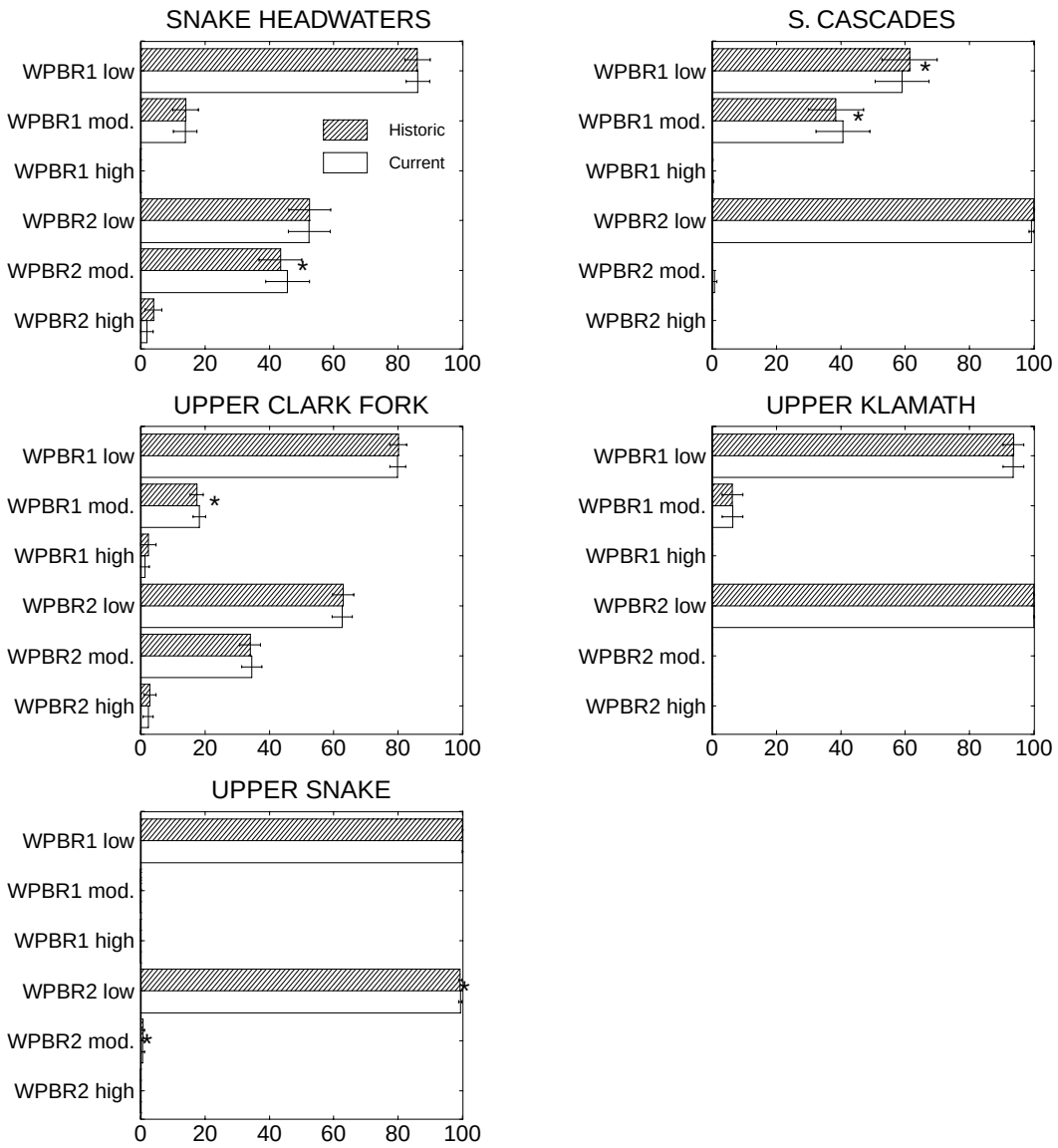


Figure 55—Historical and current distribution of white pine blister rust type-1 and type-2 disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. Pathogen disturbance abbreviations are WPBR1 = white pine blister rust (type 1) of western white and sugar pine and WPBR2 = white pine blister rust (type 2) of whitebark pine. Vulnerability class codes are low, moderate, and high.

Lower Clark Fork ERU—The Upper Coeur d'Alene (UCD) was the only subbasin sampled within the Lower Clark Fork ERU (fig. 7). Many changes in area and connectivity of vulnerability classes were observed, but few were significant at P≤0.2 owing to the small sample size.

Insect disturbance vulnerabilities—
Defoliators—Area vulnerable to western spruce budworm disturbance increased during the sample period, but the change was not significant at P≤0.2 (fig. 46); percentage of area in the high vulnerability class rose from 56.8 to 65.0 percent (ns). Further sampling and study are needed to establish the trend.

Bark beetles—Area vulnerable to the mountain pine beetle (type 1) disturbance of high density lodgepole pine increased dramatically. Percentage of area in the high vulnerability class rose more than threefold from an average of 4.0 to 12.9 percent of the ERU (fig. 48). Area in the low vulnerability class declined from an average of 30.0 to 17.3 percent of the ERU, patch density rose nearly twofold from 28.8 to 49.4 patches per 10 000 ha, and mean patch size fell from 150.1 to 36.4 ha. Our results indicated that total patch area comprised of lodgepole pine in pure and mixed compositions has changed little during the sample period, but patches in the existing condition are comprised of larger and older host trees.

Area and connectivity of patches vulnerable to fir engraver disturbance increased, but changes were not significant at P≤0.2 (fig. 49). Percentage of area in the high vulnerability class rose from an average of 28.3 to 37.0 percent (ns), and mean patch size increased from 129.7 to 171.8 ha (ns). Further sampling and study are needed to establish the trend.

Pathogen disturbance vulnerabilities—
Dwarf mistletoes—Area and connectivity of area vulnerable to lodgepole pine dwarf mistletoe disturbance increased, but change in area was not significant at P≤0.2 (fig. 51). Percentage of area in the high vulnerability class rose more than tenfold from an average of 0.2 to 2.6 percent of the ERU (ns), and mean patch size increased more than threefold from 9.1 to 31.2 ha. Further sampling and study are needed to establish the trend.

Root diseases—Area vulnerable to *Armillaria* root disease disturbance increased dramatically, but the change was not significant at P≤0.2 (fig. 52). Percentage of area in the high vulnerability class rose from 55.0 to 65.1 percent of the ERU (ns). Further sampling is needed to establish the trend.

Northern Cascades ERU—Subbasins sampled within the Northern Cascades ERU (figs. 5 and 9) included the Methow (MET), Wenatchee (WEN), Naches (NAC), Upper Yakima (UYK), and Lower Yakima (LYK). Among these subbasins, 48 historical and current subwatershed pairs were sampled.

Insect disturbance vulnerabilities—
Bark beetles—Connectivity of patches vulnerable to Douglas-fir beetle disturbance declined; patch density rose from 6.2 to 8.2 patches per 10 000 ha, and mean patch size declined by 40 percent from 149.9 to 89.2 ha (appendix 3). Connectivity of patches in the moderate vulnerability class also declined; patch density rose from 11.8 to 15.2 patches per 10 000 ha, and mean patch size declined from 376.5 to 274.8 ha. Percentage of area in the low vulnerability class rose from 65.1 to 68.4 percent of the ERU (fig. 46). Overall, area comprised of Douglas-fir cover increased, but reduced area in the high vulnerability class was the result of reduced patch area with medium and large Douglas-fir in old forest and other structures (tables 20 and 21).

Area and connectivity of area vulnerable to western pine beetle (type 1) disturbance of mature and old ponderosa pine declined (fig. 47). Percentage of area in the high vulnerability class fell from an average of 3.7 to 1.8 percent of the ERU, and mean patch size declined from 74.5 to 42.8 ha (appendix 3). Area and connectivity of patches in the moderate vulnerability class also declined; percentage of area fell from 11.8 to 8.9 percent, and mean patch size declined from 153.9 to 89.4 ha. Percentage of area in the low vulnerability class rose by a corresponding amount. The observed decline in area of high vulnerability was the result of significantly reduced area of ponderosa pine cover and reduced patch area with medium and large ponderosa pine in old forest and other structures (appendix 2).

Area and connectivity of area vulnerable to western pine beetle (type 2) and mountain pine beetle (type 2) disturbance of immature, high density ponderosa pine also declined (figs. 47 and 48). Percentage of area in the high vulnerability class fell from an average of 9.8 to 8.2 percent of the ERU, and mean patch size declined from an average of 227.4 to 96.8 ha (appendix 3). Connectivity of patches in the moderate vulnerability class also declined; patch density rose from 13.5 to 17.4 patches per 10 000 ha, and mean patch size declined from 631.7 to 369.6 ha. Decline in area of high vulnerability was the result of significantly reduced area of ponderosa pine cover in pure and mixed composition and young and middle-aged structures.

Pathogen disturbance vulnerabilities— *Dwarf mistletoes*—Area and connectivity of area vulnerable to western (ponderosa pine) dwarf mistletoe disturbance declined (fig. 51); percentage of area in the high vulnerability class fell from 5.6 to 3.9 percent of the ERU, patch density remained unchanged, and mean patch size declined by 51 percent from 87.0 to 42.5 ha (appendix 3). Area and connectivity of area in the moderate vulnerability class also declined; percentage of area fell from 13.0 to 10.8 percent, patch density rose from 7.1 to 9.2 patches per 10 000 ha, and mean patch size declined by 42 percent from 156.3 to 90.4 ha. The observed decline in area of high vulnerability was the result of significantly reduced area of ponderosa pine cover and reduced patch area with medium and large ponderosa pine in multilayered, pine-dominated structures. In many cases, ponderosa pine overstories were absent in the current condition; in others, pine-dominated understories gave way to those dominated by shade-tolerant Douglas-fir and grand fir.

Root diseases—Results of root disease analyses were quite interesting in the Northern Cascades ERU. Area and connectivity of patches vulnerable to *Armillaria* root disease disturbance declined (fig. 52); percentage of area in the high vulnerability class fell from 48.6 to 45.2 percent of the ERU, patch density rose from 10.7 to 12.4 patches per 10 000 ha, and mean patch size declined by 17 percent from an average of 681.2 to 563.9 ha (appendix 3). Rules for classifying patch vulnerability to root diseases (including root and butt rots) rated patches with larger host trees as more vulnerable to disturbance (that is, more vulnerable to change in structure and composition as a consequence of disturbance) than those with small host trees. The reason was simple: when medium and large overstory host trees succumb to root disease, canopy gaps develop, and patch structure and composition are altered; when small host trees are killed by root disease either in the overstory or understory, there is little or no substantive alteration of structure or composition. The observed decline in area of high vulnerability to *Armillaria* root disease disturbance was the result of declining area occupied by large host trees, primarily Douglas-fir. Patches comprised of hosts in the current vegetation condition will tend to be less vulnerable to structural or compositional change until host species are large enough to dominate patch structure and composition.

Area and connectivity of patches vulnerable to laminated root rot disturbance declined similarly (fig. 52); percentage of area in the high vulnerability class fell from an average of 41.7 to 39.2 percent of the ERU, patch density rose from 8.5 to 10.4 patches per 10 000 ha, and mean patch size declined by 35 percent from an average of 837.9 to 541.1 ha (appendix 3). As noted above, the observed decline in area of high vulnerability to laminated root rot disturbance was the result of declining area occupied by large host trees, primarily Douglas-fir.

Area vulnerable to S-group annosum root disease disturbance increased during the sample period (fig. 53). Percentage of area in the high vulnerability class rose by 9 percent from an average of 29.6 to 32.2 percent of the ERU. The observed increase in high vulnerability area was associated with increased area and stature of grand fir and Pacific silver fir cover (appendix 2) and increased area with visible logging entry. Area and connectivity of patches vulnerable to P-group annosum root disease disturbance declined (fig. 53); percentage of area in the high vulnerability class fell by 21 percent from an average of 7.5 to 5.9 percent of the ERU, and mean patch size fell by 34 percent from 114.1 to 74.9 ha. Area and

connectivity of area in the moderate vulnerability class also declined. The observed decline in area of high vulnerability was the result of significantly reduced area of the ponderosa pine cover type and reduced patch area with medium and large ponderosa pine in single-layered and multilayered, pine-dominated structures.

Area vulnerable to tomentosus root and butt rot disturbance declined during the sample period (fig. 54); percentage of area fell from an average of 11.4 to 9.9 percent of the ERU. Decline in vulnerable area was associated with the loss of subalpine fir-Engelmann spruce cover and declining abundance of medium and large Engelmann spruce. Similarly, area and connectivity of patches vulnerable to Schweinitzii root and butt rot disturbance declined; percentage of area in the high vulnerability class fell from an average of 61.2 to 57.2 percent of the ERU (fig. 54), patch density rose from 5.9 to 7.6 patches per 10 000 ha, and mean patch size dropped sharply by 32 percent from 1855.9 to 1266.6 ha. The observed decline in area of high vulnerability to Schweinitzii root and butt rot disturbance was the result of declining area occupied by large host trees, primarily Douglas-fir, ponderosa pine, and Engelmann spruce.

Rusts—Area and connectivity of patches vulnerable to white pine blister rust (type 1) disturbance of sugar and western white pine (western white pine in the Northern Cascades ERU) increased (fig. 55); percentage of area in the high vulnerability class rose from 0.1 to 0.2 percent of the ERU, and mean patch size increased from 2.2 to 6.7 ha. The slight but significant increase in area in the high vulnerability class was likely the result of management efforts by the Wenatchee and Okanogan National Forests to outplant white pine blister rust-resistant stock (personal observation of the senior author). Area and connectivity of patches vulnerable to white pine blister rust (type 2) disturbance of whitebark pine also increased (fig. 55); percentage of area in the high vulnerability class rose from an average of 0.4 to 0.9 percent of the ERU, patch density rose from an average of 0.8 to 1.1 patches per 10 000 ha, and mean patch size more than doubled, increasing from 11.5 to 24.5 ha (appendix 3). Increase in high vulnerability area was associated with the observed increase in percentage of area in the whitebark pine-subalpine larch cover type (appendix 2).

Stem decays—Area vulnerable to rust-red stringy rot gap disturbance increased during the sample period (fig. 56). Percentage of area in the high vulnerability class rose from an average of 0.6 to 1.1 percent of the ERU. The observed increase in high vulnerability area was associated with increased area and stature of grand fir and Pacific silver fir cover (appendix 2).

Northern Glaciated Mountains ERU— Subbasins sampled within the Northern Glaciated Mountains ERU (figs. 6 to 8) included the Lower Flathead (LFH), Kettle (KET), Pend Oreille (PEN), Sanpoil (SPO), Swan (SWN), and Yaak (YAA). Among these subbasins, 41 historical and current subwatershed pairs were sampled.

Insect disturbance vulnerabilities— *Defoliators*—Area vulnerable to western spruce budworm disturbance increased during the sample period (fig. 46). Percentage of area in the high vulnerability class increased by 8 percent from 44.5 to 47.9 percent of the ERU. The observed increase in high vulnerability area was associated with increased area of grand fir and subalpine fir-Engelmann spruce cover (appendix 2). Connectivity of high vulnerability area declined; patch density rose from 12.2 to 16.5 patches per 10 000 ha, and mean patch size declined by 64.4 ha from 806.8 ha (ns).

Bark beetles—Perhaps the most significant change in area vulnerable to bark beetle disturbance was associated with mountain pine beetle (type 1) disturbance of high density lodgepole pine. Percentage of area in the high vulnerability class rose by 23 percent from an average of 15.4 to 18.9 percent of the ERU (fig. 48). Patch density rose by 70 percent from an average of 9.3 to 15.8 patches per 10 000 ha (appendix 3), and mean patch size was unchanged. No significant change in area of the lodgepole pine cover type was observed where lodgepole pine was the principal cover species (appendix 2), but our results suggested that current areas of lodgepole pine exhibit larger host size, poorer overstory crown differentiation,

higher total crown cover, and greater contiguity of these characteristics than occurred in the historical condition. It appears that large areas became synchronously more vulnerable to mountain pine beetle (type 1) disturbance during the sample period.

Area and connectivity of patches vulnerable to spruce beetle disturbance increased (fig. 49); percentage of area in the high vulnerability class rose from an average of 3.0 to 4.5 percent of the ERU, patch density increased from 2.6 to 4.7 patches per 10 000 ha, and mean patch size increased by 71 percent from 46.6 to 79.9 ha (appendix 3). Increased area in high vulnerability patches was associated with increased area and stature of spruce in the subalpine fir-Engelmann spruce cover type.

Pathogen disturbance vulnerabilities—
Dwarf mistletoes—Area and connectivity of patches vulnerable to western (ponderosa pine) dwarf mistletoe disturbance declined (fig. 51); percentage of area in the high vulnerability class fell by 34 percent from an average of 3.8 to 2.5 percent of the ERU area, patch density remained unchanged, and mean patch size declined by 72 percent from an average of 57.1 to 16.0 ha (appendix 3). The observed decline in area of high vulnerability was the result of significantly reduced area of ponderosa pine cover (appendix 2) and reduced patch area with medium and large ponderosa pine in multilayered, pine-dominated structures. In many patches, ponderosa pine overstories were absent in the current condition; in others, pine-dominated understories gave way to shade-tolerant Douglas-fir and grand fir.

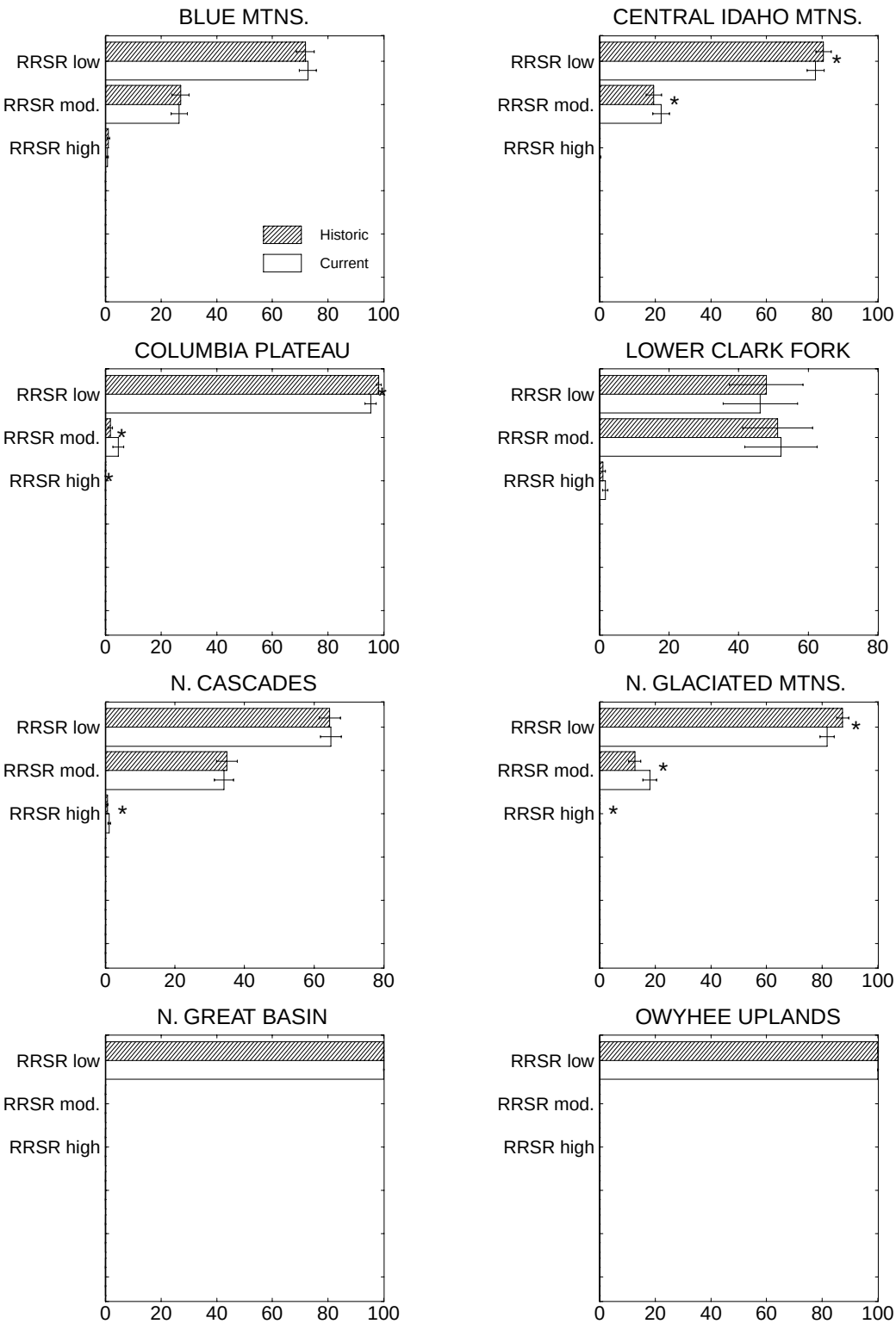
Area vulnerable to western larch dwarf mistletoe disturbance declined (fig. 50); percentage of area in the high vulnerability class declined by 39 percent, falling from 6.9 to 4.2 percent, and mean patch size declined from an average of 57.6 to 38.5 ha (appendix 3). Area and connectivity of patches in the moderate vulnerability class also declined. The observed decline in area of high vulnerability was the result of significantly reduced area of western larch cover, and reduced patch area with medium and large western larch in multilayered, larch-dominated structures (appendix 2). In many patches, western larch overstories were absent in the current condition; in others, larch understories gave way to shade-tolerant Douglas-fir, grand fir, subalpine fir, western hemlock, and western redcedar.

Root diseases—Area vulnerable to *Armillaria* root disease disturbance increased (fig. 52) and connectivity of vulnerable patches declined (appendix 3). Percentage of area in the high vulnerability class rose from an average of 37.3 to 40.7 percent of the ERU, patch density rose from an average of 14.1 to 20.8 patches per 10 000 ha, and mean patch size remained relatively stable. The observed increase in area of high vulnerability was the result of significantly increased area of grand fir and subalpine fir-Engelmann spruce cover types.

Area and connectivity of patches vulnerable to S-group annosum root disease disturbance increased (fig. 53); percentage of area in the high vulnerability class rose by 34 percent from 20.0 to 26.8 percent of the ERU, patch density more than doubled from an average of 9.3 to 20.5 patches per 10 000 ha from 9.3 patches, and mean patch size was unchanged. The observed increase in area of high vulnerability was the result of increased area of grand fir, subalpine fir-Engelmann spruce, and western hemlock-western redcedar cover (appendix 2); increased patch area with understories comprised of shade-tolerant Douglas-fir, grand fir, subalpine fir, and western hemlock; and increased area with visible logging entry.

Area and connectivity of area vulnerable to tomentosus root and butt rot disturbance also increased (fig. 54); percentage of area in the high vulnerability class rose from 7.1 to 9.0 percent, patch density rose from 5.9 to 10.8 patches per 10 000 ha (appendix 3), and mean patch size was unchanged. The observed increase in area of high vulnerability was the result of increased area of the subalpine fir-Engelmann spruce cover type with medium and large Engelmann spruce.

Rusts—Area and connectivity of patches vulnerable to white pine blister rust (type 1) disturbance of sugar and western white pine (western white pine in the Northern Glaciated Mountains) declined significantly (fig. 55); percentage of area


BLUE MTNS.
CENTRAL IDAHO MTNS.
COLUMBIA PLATEAU
LOWER CLARK FORK
N. CASCADES
N. GLACIATED MTNS.
N. GREAT BASIN
OWYHEE UPLANDS
RRSR low
RRSR mod.
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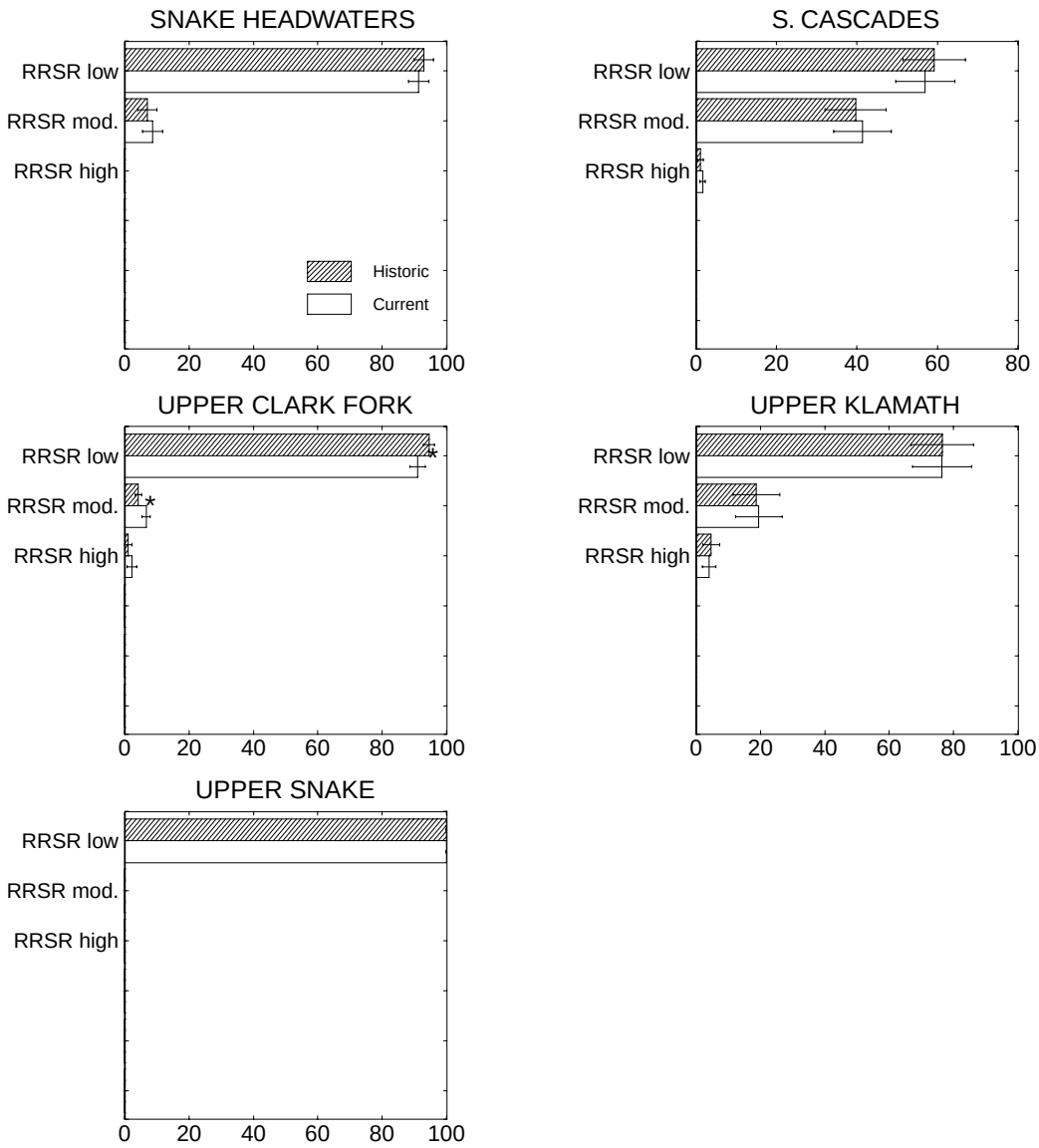

Figure 56—Historical and current distribution of rust-red stringy rot disturbance vulnerability classes expressed as a percentage of total area on all ownerships in ERUs of the interior Columbia River basin. Error bars indicate the standard error of the mean estimate. Asterisks indicate a significant (P≤0.2) difference between historical and current conditions. RRSR = rust-red stringy rot. Vulnerability class codes are low, moderate, and high.

in the high vulnerability class fell by 84 percent from an average of 1.9 to 0.3 percent of the ERU. Mean patch size declined by the same proportion, falling from an average of 26.3 to 4.2 ha (appendix 3). The observed decline in high vulnerability area was likely the result of more than eight decades of blister rust mortality and early selective harvest of western white pine.

Stem decays—Area and connectivity of area vulnerable to rust-red stringy rot disturbance increased slightly; percentage of area in the high vulnerability class rose from an average of 0 to 0.2 percent of the ERU (fig. 56 and appendix 3). The observed increase in area of high vulnerability was the result of increased area of grand fir and subalpine fir-Engelmann spruce cover and increased patch area with understories comprised of shade-tolerant grand fir and subalpine fir.

Northern Great Basin ERU—The Donner und Blitzen (DUB) is the only subbasin sampled within the Northern Great Basin ERU (fig. 16); four historical and current subwatershed pairs were sampled. Forests of the ERU represented a minor area and were comprised of aspen, cottonwood, and juniper. Hosts of the insects and pathogens modeled were not present in the ERU.

Owyhee Uplands ERU—Subbasins sampled within the Owyhee Uplands ERU (figs. 21 and 22) included the Big Wood (BWD), Crooked Rattlesnake (CRT), and Upper Owyhee (UOW). Among these subbasins, 21 historical and current subwatershed pairs were sampled. Forests of the ERU represented a minor area and were comprised chiefly of aspen and cottonwood. Woodland cover was dominated by juniper. With the exception of juniper, which is host to P-group annosum root disease, hosts of the insects and pathogens modeled were not present in the ERU.

Snake Headwaters ERU—Subbasins sampled within the Snake Headwaters ERU (fig. 19) included the Lower Henry's (LHE), Palisades (PSD), and Snake Headwaters (SHW). Among these subbasins, 15 historical and current subwatershed pairs were sampled.

Insect disturbance vulnerabilities—
Defoliators—Area and connectivity of patches vulnerable to western spruce budworm disturbance increased during the sample period (fig. 46). Percentage of area in the high vulnerability class rose from an average of 45.0 to 51.8 percent of the ERU area, patch density remained unchanged, and mean patch size increased by 37 percent from an average of 333.1 to 455.5 ha (appendix 3). The observed increase in high vulnerability area was associated with dramatically increased area of subalpine fir-Engelmann spruce cover in multilayered structural arrangements (tables 23 and 24 and appendix 2).

Bark beetles—Area and connectivity of patches vulnerable to Douglas-fir beetle disturbance increased during the sample period. Percentage of area in the high vulnerability class increased by 86 percent from an average of 2.1 to 3.9 percent of the ERU (fig. 46), patch density increased from 5.1 to 7.1 patches per 10 000 ha, and mean patch size increased by 80 percent from an average of 17.5 to 31.6 ha (appendix 3). Because total area in old forest structures declined from 5.2 to 3.1 percent of the ERU (appendix 2), most of the increased area in the high vulnerability class was likely associated with increased abundance of medium and large Douglas-fir in structural classes other than old forest.

The most significant change in area vulnerable to bark beetle disturbance was associated with mountain pine beetle (type 1) of high density lodgepole pine. Percentage of area in the high vulnerability class fell by 16 percent from an average of 34.6 to 29.2 percent of the ERU (fig. 48). Percentage of area in the moderate vulnerability class rose by a corresponding amount. Area of the lodgepole pine cover type declined during the sample period from 15.6 to 11.3 percent of the ERU. These results suggest that area of pole-sized and larger lodgepole pine in both pure and mixed compositions declined during the sample period, perhaps as a consequence of historical mountain pine beetle disturbance.

Connectivity of patches vulnerable to fir engraver disturbance declined (fig. 49); patch density increased from an average of 10.8 to 18.1 patches per 10 000 ha, and mean patch size declined by 38 percent from an average of 211.3 to 131.9 ha (appendix 3). Percentage of area highly vulnerable to fir engraver disturbance declined from an average of 19.3 to 16.1 percent of the ERU, but the change was not significant at this reporting scale. Area vulnerable to spruce beetle disturbance declined significantly (fig. 49); percentage of area in the high vulnerability class fell from 8.3 to 7.6 percent of the ERU. Percentage of area in the moderate vulnerability class fell from 39.2 to 35.3 percent. Area of subalpine fir-Engelmann spruce cover increased by 30 percent during the sample period from an average of 24.3 to 31.4 percent of the ERU area. These results suggest that area of medium and large Engelmann spruce in mixed compositions declined during the sample period.

Pathogen disturbance vulnerabilities— *Dwarf mistletoes*—Area and connectivity of patches vulnerable to Douglas-fir dwarf mistletoe disturbance increased (fig. 50). Percentage of area rose from 4.1 to 6.4 percent of the ERU, representing a 56-percent increase from the historical condition, and mean patch size sharply increased more than twofold from 19.2 to 49.6 ha (appendix 3). Increased area in the high vulnerability class was associated with expanded area of Douglas-fir in mixed species compositions, increased canopy layering, and contiguity of host patches. Area and connectivity of patches vulnerable to lodgepole pine dwarf mistletoe declined (fig. 51). Percentage of area in the high vulnerability class fell sharply by 32 percent from an average of 30.8 to 20.9 percent of the ERU, and mean patch size declined from 274.3 to 186.6 ha (appendix 3). Area in the low and moderate vulnerability classes increased by a corresponding amount. Area of lodgepole pine cover declined during the sample period, but not enough to account for the observed decline in high vulnerability area. Our results indicated that area in lodgepole pine occurring in pure and mixed compositions and in multilayered structures declined significantly during the sample period.

Root diseases—Area and connectivity of patches vulnerable to *Armillaria* root disease disturbance increased significantly (fig. 52); percentage of area increased by 54 percent from an average of 20.4 to 31.5 percent of the ERU area, and mean patch size nearly doubled from 106.6 to 205.4 ha (appendix 3). Increased area in the high vulnerability class was associated with expanded area of subalpine fir and Douglas-fir in pure and mixed species compositions, increased crown cover of host species, and increased contiguity of host patches. Area and connectivity of patches vulnerable to laminated root rot disturbance also increased; percentage of area rose from 10.9 to 12.8 percent of the ERU, and mean patch size increased from an average of 71.4 to 100.8 ha.

Area and connectivity of patches vulnerable to S-group annosum root disease disturbance increased (fig. 53). Percentage of area rose sharply by 39 percent from an average of 22.0 to 30.6 percent of the ERU area, and mean patch size increased from an average of 141.1 to 204.0 ha. Area of the low and moderate vulnerability class changed by a compensating amount. Increased area in the high vulnerability class was associated with expanded area of subalpine fir in pure and mixed species compositions, increased crown cover of host species, increased contiguity of host patches, and increased area with visible logging entry.

Southern Cascades ERU—Subbasins sampled within the Southern Cascades ERU (fig. 15) included the Little Deschutes (LDS), and Upper Deschutes (UDS). Within these subbasins, 16 historical and current subwatershed pairs were sampled.

Insect disturbance vulnerabilities— *Defoliators*—Area vulnerable to western spruce budworm disturbance increased; percentage of area in the high vulnerability class increased by 22 percent from an average of 10.1 to 12.3 percent of the ERU (fig. 46). Connectivity declined significantly in all vulnerability classes (appendix 3), indicating that highly vulnerable areas were fewer and larger historically, but today are more numerous and interspersed.

Bark beetles—Area vulnerable to Douglas-fir beetle disturbance declined (fig. 46); percentage of area fell by 94 percent from an average of 1.8 to 0.1 percent of the ERU. Decline in high vulnerability area was associated with reduced area and connectivity of patches having large Douglas-fir in structures other than old forest (table 20).

The most significant change in area vulnerable to bark beetle disturbance was associated with mountain pine beetle (type 1) of high density lodgepole pine. Percentage of area in the high vulnerability class fell from an average of 29.0 to 24.9 percent of the ERU (ns); percentage of area in the moderate vulnerability class rose from 34.9 to 39.5 percent (fig. 48). Area of the lodgepole pine cover type actually increased slightly during the sample period from 19.4 to 20.6 percent, but the change was not significant at $P \leq 0.2$. Our results suggest that area of lodgepole pine in historically mixed compositions declined during the sample period as a result of well-documented mountain pine beetle outbreaks in central Oregon (Mitchell 1987, Mitchell and Preisler 1991, and references therein) and fire exclusion.

Pathogen disturbance vulnerabilities—
Dwarf mistletoes—Area and connectivity of patches vulnerable to Douglas-fir dwarf mistletoe disturbance declined (fig. 50); percentage of area in the high vulnerability class declined by 78 percent, from an average of 2.3 to 0.5 percent of the ERU, and mean patch size declined by a similar proportion from an average of 95.1 to 24.1 ha (appendix 3). The observed decline in area of high vulnerability was the result of significantly reduced patch area and contiguity with medium and large Douglas-fir in multilayered structures.

Root diseases—Area vulnerable to *Armillaria* root disease disturbance increased (fig. 52). Percentage of area rose 17 percent from an average of 10.9 to 12.8 percent of the ERU, patch density increased from an average of 3.5 to 6.1 patches per 10 000 ha, and mean patch size declined from 230.0 to 171.4 ha (ns). Area vulnerable to laminated root rot disturbance also increased (fig. 52); percentage of area rose by 14 percent from an average of 31.1 to 35.4 percent of the ERU. Increased area in *Armillaria* root disease and laminated root rot high vulnerability classes was associated with expanded area of subalpine fir, grand fir, and Douglas-fir in mixed species compositions, expanded area of shade-tolerant understories, and increased crown cover of host species (table 24 and appendix 2).

Area and connectivity of patches vulnerable to P-group annosum root disease disturbance increased (fig. 53). Percentage of area rose 70 percent from an average of 13.8 to 23.4 percent of the ERU area, patch density increased from 3.6 to 5.8 patches per 10 000 ha, and mean patch size increased by 51 percent from 541.6 to 816.2 ha (ns). Increased area in the high vulnerability class was associated with regrowth of ponderosa pine in pure and mixed species compositions, increased crown cover of host species, and increased contiguity of host patches.

Upper Clark Fork ERU—Subbasins sampled within the Upper Clark Fork ERU (figs. 8 and 11) included the Blackfoot (BFM), Bitterroot (BTR), and Flint Rock (FLR). Among these subbasins, 32 historical and current subwatershed pairs were sampled.

Insect disturbance vulnerabilities—
Bark beetles—Area and connectivity of patches vulnerable to Douglas-fir beetle disturbance declined during the sample period. Percentage of area in the high vulnerability class fell by 40 percent from an average of 8.0 to 4.8 percent of the ERU (fig. 46), patch density increased from 5.4 to 10.0 patches per 10 000 ha, and mean patch size declined by 61 percent from 114.6 to 44.4 ha. Loss of area in the high vulnerability class was the result of reduced crown cover of large and medium Douglas-fir across all forest structural classes.

Another significant change in area vulnerable to bark beetle disturbance was associated with western pine beetle (type 1) disturbance of mature and old ponderosa pine. Percentage of area in the high vulnerability class declined sharply by 83 percent from an average of 2.9 to 0.5 percent of the ERU (fig. 47). Area of ponderosa pine cover decreased from 12.3 to 9.5 percent of the ERU (appendix 2). Loss of high vulnerability area was primarily associated with reduced area in the ponderosa pine cover type and reduced crown cover of medium and large ponderosa pine across all forest structural classes.

Area vulnerable to western pine beetle (type 2) and mountain pine beetle (type 2) disturbance of immature, high-density ponderosa pine also declined during the sample period (figs. 47 and 48). Percentage of area in the high vulnerability class fell from 9.9 to 8.1 percent, an 18-percent loss of area during the sample period. Loss of high vulnerability area was associated primarily with reduced area in the ponderosa pine cover type and reduced area of stem-exclusion, understory reinitiation, and young multistory structures with ponderosa pine in pure or mixed compositions.

Area and connectivity of patches vulnerable to fir engraver disturbance increased during the sample period (fig. 49); percentage of area in the high vulnerability class rose by 24 percent from an average of 7.8 to 9.7 percent of the ERU, patch density increased from 6.4 to 8.7 patches per 10 000 ha, and mean patch size increased from 88.0 to 111.0 ha (ns). High vulnerability area increased as consequence of increased area in the subalpine fir-Engelmann spruce cover type in all forest structural classes but stand initiation.

Pathogen disturbance vulnerabilities—
Dwarf mistletoes—Area and connectivity of patches vulnerable to the Douglas-fir, ponderosa pine, and western larch dwarf mistletoes disturbance declined during the sample period (figs. 50 and 51). Percentage of area in the Douglas-fir dwarf mistletoe high vulnerability class fell by 19 percent from an average of 16.2 to 13.2 percent of the ERU (fig. 50), patch density increased 25 percent from an average of 12.3 to 15.4 patches per 10 000 ha, and mean patch size declined by 50 percent from an average of 154.0 to 75.1 ha (appendix 3). The observed decline in area of high vulnerability was the result of significantly reduced patch area and contiguity with medium and large Douglas-fir in multilayered structures. Area and connectivity of area vulnerable to western (ponderosa pine) dwarf mistletoe disturbance also declined (fig. 51); percentage of area in the high vulnerability class fell by 54 percent from an average of 5.0 to 2.3 percent of the ERU, and mean patch size declined 59 percent from an average of 50.2 to 20.4 ha. The observed decline in area of high vulnerability was the result of significantly reduced patch area and contiguity with medium and large ponderosa pine in multilayered structures. Area and connectivity of patches vulnerable to western larch dwarf mistletoe disturbance followed a similar pattern (fig. 50).

Root diseases—Area and connectivity of patches vulnerable to P-group annosum root disease disturbance declined (fig. 53); percentage of area in the high vulnerability class fell from 5.4 to 4.0 percent of the ERU, patch density increased from 3.3 to 4.5 patches per 10 000 ha, and mean patch size declined from an average of 51.8 to 39.4 ha (ns). The observed decline in area of high vulnerability was the result of reduced patch area and contiguity with medium and large ponderosa pine.

Upper Klamath ERU—Subbasins sampled within the Upper Klamath ERU (fig. 20) included the Lost (LST) and Upper Klamath Lake (UKL). Among these subbasins, 12 historical and current subwatershed pairs were sampled.

Insect disturbance vulnerabilities—
Bark beetles—Area and connectivity of patches vulnerable to western pine beetle (type 1) disturbance of mature and old ponderosa pine declined, but only change in connectivity was significant (fig. 47). Percentage of area in the high vulnerability class fell from an average of 5.7 to 4.5 percent of the ERU, patch density increased from 3.5 to 4.9 patches per 10 000 ha, and mean patch size declined from 67.6 to 51.1 ha (ns). Decline in connectivity of high vulnerability patches was the result of significantly reduced area of ponderosa pine cover and reduced patch area with medium and large ponderosa pine, especially in old single-story forest structures (tables 20 and 21).

Area and connectivity of patches vulnerable to fir engraver disturbance increased during the sample period; percentage of area in the high vulnerability class rose from an average of 17.1 to 18.0 percent of the ERU (fig. 49), patch density declined from 3.7 to 2.0 patches per 10 000 ha (appendix 3), and mean patch size rose from 586.7 to 700.1 ha (ns). High vulnerability area increased as consequence of expanded area in the grand fir-white fir and Shasta red fir cover types.

Pathogen disturbance vulnerabilities—
Root diseases—Area vulnerable to Schweinitzii root and butt rot disturbance declined sharply by 32 percent, falling from an average of 26.4 to 17.9 percent of the ERU (fig. 54). Decline in area of high vulnerability to Schweinitzii root and butt rot disturbance was the result of declining area occupied by medium and large host trees, primarily Douglas-fir and ponderosa pine in old-forest single-story and other forest structures (tables 20 and 21 and appendix 2).

Upper Snake ERU—Subbasins sampled within the Upper Snake ERU (figs. 18, 19, and 22) included the Lower Henry's (LHE), Lake Walcott (LWC), and Medicine Lodge (MDL). Among these subbasins, 15 historical and current subwatershed pairs were sampled. Less than 5 percent of the area of the ERU is comprised of forest cover types. Forest settings are cold and dry, occurring in upper montane and subalpine settings. Two significant vulnerability changes were associated with increased area of Douglas-fir.

Insect disturbance vulnerabilities—
Defoliators—Area and connectivity of patches vulnerable to western spruce budworm disturbance increased (fig. 46). Percentage of area in the high vulnerability class rose from 1.6 to 2.1 percent, representing a 31-percent increase from the historical condition. Patch density declined from 1.1 to 0.5 patch per 10 000 ha, and mean patch size increased threefold from an average of 32.4 to 95.4 ha (appendix 3).

Pathogen disturbance vulnerabilities—
Dwarf mistletoes—Area and connectivity of patches vulnerable to Douglas-fir dwarf mistletoe increased but only the change in connectivity was significant (fig. 50). Percentage of area in the high vulnerability class rose from 0.6 to 1.5 percent of the ERU (ns), patch density declined from 1.8 to 1.1 patches per 10 000 ha, and mean patch size more than tripled from an average of 5.3 to 18.8 ha, but the increase was not statistically significant at this scale.

Root diseases—Area and connectivity of patches vulnerable to *Armillaria* root disease increased, but only change in connectivity was statistically significant (fig. 52). Patch density declined from 2.1 to 1.1 patches per 10 000 ha, and mean patch size more than doubled from 9.2 to 21.0 ha (ns). Connectivity of patches vulnerable to S-group annosum root disease increased similarly (appendix 3); patch density declined from 2.3 to 0.9 patch per 10 000 ha, and mean patch size tripled from 10.2 to 31.7 ha (ns).

Area and connectivity of patches vulnerable to Schweinitzii root and butt rot disturbance increased. Percentage of area in the high vulnerability class rose from an average of 1.5 to 2.1 percent (fig. 54), and mean patch size jumped from 20.4 to 57.8 ha (appendix 3). Area in the Douglas-fir cover type increased most significantly in stem-exclusion open canopy and young multistory structures.

Discussion

Detecting Ecosystem Change

To detect significant vegetation change of forest or rangeland ecosystems, vegetation attributes must change similarly across sampled subwatersheds of a statistical pooling stratum. Despite our efforts to sample large landscapes to minimize area bias in landscape metrics and a sampling intensity of at least 15 percent of subbasin area, our sample size was still relatively small given the geographic extent and spatial heterogeneity of subbasins within ERUs. Even though we detected many significant changes at the ERU scale, we learned that likelihood was high of falsely accepting that no difference exists between historical and current conditions of some attributes of ERUs. We suggest that much greater change has occurred than we were able to detect at the scale of the ERU, and that the change analysis will be more potent and revealing where subwatersheds of similar climate, biophysical environment, and potential vegetation conditions are grouped for analysis.

Ecological reporting units were developed by the Science Team in response to an executive decision to summarize results of all broad-scale ecological, social, and economic assessments of the project by province-scale units. That decision also dictated that results of midscale analysis would be summarized by ERU rather than by our initial sample strata. Summarization by ERUs enabled comparison of results between broadscale (Hann and others 1997) and midscale landscape assessments, but it also pooled tremendous environmental variation and redistributed some of the sampled subwatersheds in a less than optimal manner.

Throughout the discussion, we suggest likely causes of change based on our best interpretation of the empirical evidence, but alternative explanations are possible for the changes we detected, and these are worthy of further exploration. Some changes we observed may be the result of random chance, climate change, environmental, climate, disturbance stochasticity, or interactions among a variety of disturbance and successional processes.

Our remotely sensed current conditions were fixed reasonably well in time within sampled subbasins, but historical vegetation conditions, which provided the basis for change detection, were variable among subwatersheds, even within subbasins. On balance, we believe that a variable historical starting point was more desirable that a single historical starting point, because it gave us the potential to observe greater variability in historical vegetation attributes and patterns stemming from climatic, environmental, and disturbance stochasticity, thereby strengthening our estimation of ecologically significant change. Still, historical fires, insect outbreaks, logging activities, wild ungulate and domestic livestock grazing, other disturbance factors, and differences in landscape patterns of biophysical environments created widely differing patterns of vegetation structure and composition. Such differences in historical conditions obscured our ability to detect some changes at the ERU scale and even at smaller spatial scales, such as the subbasin. Differences associated with biophysical environmental conditions, and to some extent management history, could be minimized with regionalization—a multivariate classification and environmental mapping procedure we will present below (see “Ecological Regionalization”).

Variation in historical conditions was the result of many factors. Perhaps greatest among them was high variability in the variety and intensity of historical management activities. Within ERUs, some entire historical subwatersheds were unlogged wilderness or unburned or burned wilderness, and others had been intensively managed. In landscape-scale studies such as this one (see also Lehmkuhl and others 1994), amount, timing, and kind of management activity are difficult if not impossible factors to account for or control. We expected to observe large differences in the rate and type of change between subwatersheds managed primarily for wilderness and those managed for multiple resource objectives. But it is important not to carry the comparison too far. Throughout the basin, most wilderness watersheds occur in upper montane and subalpine environmental settings, and watersheds managed for multiple uses typically occur in low and middle montane settings. Fundamental differences in dominant potential vegetation types, disturbance and climatic regimes, and other biophysical characteristics are enormous, as are differences in response to management activities.

Throughout the basin, fire suppression, fire exclusion, and timber harvest of early seral species had the effect of dramatically advancing forest succession on a collapsed time scale, in both species composition and structural attributes. But in the current condition, other typical and essential attributes of late seral forests often are absent, including large, pathologically old live trees, native epiphytic and hypogeous flora, large standing dead and down woody structures, and native understory shrub and herbaceous communities.

As seen in wilderness and roadless areas, fire exclusion alone produced a similar effect on succession, but it occurred over a longer time frame; that is, the temporal scale was not collapsed. Fire exclusion affected change by removing a disturbance agent that normally reset one or more ecosystem components episodically; for example, in dry ponderosa pine ecosystems, exclusion of fire precipitated accumulation of high tree densities and woody residue volumes that were absent or rare under native fire regimes. At a landscape scale, fire exclusion enabled the accumulation of mid- and late-seral forests habitable by the northern spotted owl (*Strix occidentalis*), which is now apparent east of the crest of the Cascades (Everett and others 1997). Areas once dominated by early seral species, such as ponderosa pine, and frequented by surface fires are now dominated by grand fir and dwarf mistletoe-infested Douglas-fir and are infrequently visited by stand-replacing fires.

Effects of fire exclusion, although more subtle than those produced by timber harvesting, differed substantially among sampled historical subwatersheds of an ERU. Reasons for this were fairly obvious: fire regimes differ quite predictably by PVT, PVTs differ somewhat predictably with biophysical environmental setting, and subwatershed patterns of biophysical environments and potential vegetation differ greatly. Exclusion of fire for six to eight decades in settings historically visited by frequent surface fires (every 0 to 25 years) would transform nonlethal surface fire regimes to lethal crown fire regimes. But exclusion of fire for a similar period in settings historically visited by infrequent crown fires at intervals averaging 150 to 300 years would have, by comparison, an as yet negligible effect on fire regime.

Other potential sources of variation included differences in quality and photo scale between historical and current aerial photographic coverages, differences in quality and consistency of interpretations among photointerpreters, and differing period length among sampled subwatersheds within an ERU (see table 3). Quality control steps were taken to minimize these sources of variation, but the latter contributed nonetheless. Lack of significant difference for some variables between historical and current subwatershed conditions also could be related to high inherent natural variability within and among subwatersheds.

Observations of significant change, or its lack, in the period between our historical and current samples were not and should not be interpreted as effects from a pristine pre-European settlement initial condition. We assumed in this study that considerable change in forest and range vegetation structure and composition had already taken place throughout the 58-million-hectare basin

assessment area before the time of our historical starting point sample (Anderson and others 1987; Antos 1977; Antos and Habeck 1981; Arno 1976, 1980; Arno and Davis 1980; Arno and Peterson 1983; Barrett and Arno 1982; Barrett and others 1991; Bevins and Barney 1980; Bork 1985; Christensen 1985, 1988; Cooper 1926, 1961a, 1961b; Daubenmire 1968; Daubenmire and Daubenmire 1968; Davis and others 1980; Dickman and Cook 1989; Fahnestock 1976; Finch 1984; Franklin and others 1971; Galbraith and Anderson 1991; Gara and others 1985; Geiszler and others 1980; Gruell and others 1982; Hall 1976; Kauffman 1990; Keen 1937; Knudsen 1980; Martin and others 1976; McNeil and Zobel 1980; Morris 1934a, 1934b; Nordin 1958; Oliver 1981; Oliver and Larson 1990; Pyne 1982; Savage and Swetnam 1990; Soeriaatmadja 1966; Stuart and others 1989; Vale 1975; Weaver 1959, 1961; Wischnofske and Anderson 1983; Wright and Klemmedson 1965; Young and Evans 1981; Young and others 1987). Rates, magnitudes, and locations of older historical changes are poorly known today and will continue to be poorly understood in most areas of the basin. The historical photographs we used simply represented the oldest photographic coverages of interpretable quality and of continuous subwatershed coverage available from the Forest Service, Bureau of Land Management, or National Archives or held in private ownership. In this manner, we provide previously unavailable quantitative estimates of direction, rate, and partial magnitude of changes.

Near the start of the 20th century, the Forest Service and Bureau of Land Management inherited highly altered forest and range ecosystems. Grazing had radically changed rangeland vegetation structure and composition and forest understories, and forest burning by miners and sheep herders was a relatively common occurrence (Robbins and Wolf 1994, Wissmar 1994a, Woods and Horstman 1996). Extensive logging on Federal forest lands was uncommon in most areas of the basin until after World War II. Throughout the five decades of management and resource extraction that followed, these ecosystems were further altered, disturbed, and reconfigured.

Whether current conditions of any subwatershed in our sample are nearly natural considering the climatic regime, biophysical environmental conditions, and inherent disturbance regimes is as yet unknown to us. Information we provide on the partial magnitude and direction of change during a relatively long period of comparable climate and across a large geographic area contributes valuable insights into rates of change that can be expected both temporally and spatially. It also provides a framework from which management alternatives can be developed, tested, and monitored.

Vegetation Composition and Structure

Physiognomic types—Many predicted changes in vegetative structure and composition of basin forests and ranges associated with past management activities were largely borne out by our analysis. Causal connections, however, were difficult to establish because the timing, duration, and intensity of various management activities were not directly measured; it also was not possible to evaluate correlations between effects and potential causative factors. Increased forest cover in the Blue Mountains, Columbia Plateau, Southern Cascades, and Upper Snake ERUs (table 29 and appendix 2) suggested that effective fire exclusion resulted in forest establishment on areas that were previously bare ground or shrubland, or on herbland areas previously maintained by fire or created by early logging. Figure 57, A, provides an example of increased forest cover in a subwatershed of the Lower Grande Ronde subbasin in the Blue Mountains ERU. Significantly reduced forest cover in the Upper Klamath ERU suggested that timber harvest activities during the sample period resulted in a net depletion of forest area. Cover type and structure analysis corroborated this observation. Figure 57, B, provides an example of reduced forest cover in a subwatershed of the Upper Klamath subbasin in the Upper Klamath ERU.

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Table 29—Historical and current percentage of area for physiognomic types, cover types, and structural classes of 13 ecological reporting units in the midscale assessment of the interior Columbia River basin

	Change in percentage of area among ERUs														
	Blue Mountains[ab]			Central Idaho Mountains[ab]			Columbia Plateau[ab]			Lower Clark Fork[ab]			Northern Cascades[ab]		
Patch types	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]
	Percent														
Physiognomic types:															
Forest	62.8	64.1	1.4*	73.4	73.5	0.2	26.1	29.1	3.0*	91.7	94.5	2.8	78.8	78.2	-0.6
Woodland	2.7	4.2	1.6*	0.1	0.0	0.0	6.7	12.2	5.5*	--	--	--	0.3	0.7	0.3*
Shrubland	14.1	10.7	-3.4*	19.2	17.1	-2.0*	32.2	23.4	-8.8*	1.9	0.6	-1.4	4.8	4.1	-0.7
Herbland	17.4	18.0	0.6	3.2	4.5	1.0*	12.7	14.0	1.4	5.4	3.2	-2.3	6.7	6.5	-0.3
Other[d]	3.0	2.9	-0.1	4.2	4.9	1.0*	22.4	21.4	-1.0	0.9	1.8	0.8	9.4	10.6	1.2*
Cover types-forest and woodland:															
Pacific silver fir	--	--	--	--	--	--	--	--	--	--	--	--	6.0	8.3	2.3*
Grand fir-white fir	15.3	8.4	-6.9*	9.6	10.2	0.5	1.1	0.4	-0.7	40.4	42.5	2.1	1.0	2.2	1.3*
Engelmann spruce-subalpine fir	6.3	4.4	-1.9*	22.7	24.1	1.4	0.0	0.0	0.0	2.5	2.2	-0.3	16.8	13.6	3.2*
Aspen-cottonwood-willow	0.1	0.1	0.0	1.1	0.8	-0.2	0.3	0.3	0.0	0.1	0.7	0.6	--	--	--
Oregon white oak	--	--	--	--	--	--	--	--	--	--	--	--	0.6	0.9	0.3*
Juniper	2.7	4.2	1.5*	0.1	0.0	0.0	6.5	12.0	5.5*	--	--	--	0.0	0.0	0.0
Western larch	2.6	2.2	-0.4	0.5	0.3	-0.2*	1.0	0.1	-0.9*	0.8	2.6	1.7	1.0	1.0	0.0
Whitebark pine-subalpine larch	0.0	0.7	0.7*	5.1	2.5	-2.5	--	--	--	--	--	--	3.3	4.7	1.4*
Lodgepole pine	2.4	2.3	-0.1	9.7	9.5	-0.2	1.3	0.9	-0.4	2.1	1.8	-0.3	5.9	5.2	-0.6
Limber pine	0.0	0.0	0.0	0.4	0.4	-0.1	--	--	--	0.0	0.0	0.0	--	--	--
Sugar pine-western white pine	--	--	--	--	--	--	--	--	--	0.3	0.6	0.2	0.1	0.3	0.1*
Ponderosa pine	28.4	28.9	0.5	6.0	5.9	-0.2	19.2	21.4	2.3*	3.0	5.1	2.1	16.5	13.2	-3.2*
Douglas-fir	7.7	17.1	9.4*	17.6	18.5	1.0	3.0	3.9	0.9*	26.4	21.1	-5.3	23.8	25.8	2.0*
Western hemlock with redcedar	--	--	--	0.9	1.3	0.4	0.4	2.2	1.9*	14.7	17.3	2.6	3.0	2.4	-0.6*
Mountain hemlock	--	--	--	0.0	0.0	0.0*	0.0	0.0	0.0	1.3	0.6	-0.7*	1.3	1.2	-0.1
Cover types-shrubland:															
Colline low-medium	7.2	4.7	-2.5*	8.2	8.0	-0.3	29.1	21.7	-7.4*	--	--	--	1.6	1.8	0.2
Montane low-medium	6.0	5.4	-0.6	5.3	4.9	-0.4	1.3	0.9	-0.3	--	--	--	0.3	0.4	0.1
Subalpine-alpine low-medium	--	--	--	0.5	0.4	-0.1	--	--	--	0.2	0.1	-0.1	--	--	--
Colline mahogany species	--	--	--	0.0	0.0	0.0	0.4	0.1	-0.2	--	--	--	0.2	0.0	-0.1
Montane mahogany species	0.4	0.2	-0.1*	0.4	0.2	-0.2*	0.0	0.0	0.0	--	--	--	0.0	0.0	0.0*
Subalpine-alpine mahogany species	--	--	--	0.0	0.0	0.0	--	--	--	--	--	--	--	--	--
Colline tall	0.0	0.0	0.0	0.5	0.3	-0.3	0.3	0.1	-0.1	--	--	--	0.0	0.0	0.0
Montane tall	0.1	0.0	-0.1*	3.7	3.2	-0.5	0.9	0.4	-0.6	1.6	0.3	-1.3	0.0	0.0	0.0*
Colline wet-site	0.0	0.1	0.0	0.1	0.1	-0.1	0.2	0.1	-0.1*	0.0	0.0	0.0	0.0	0.0	0.0
Montane wet-site	0.1	0.1	0.0	0.7	0.6	-0.1*	0.1	0.1	0.0	1.4	1.4	0.1	0.0	0.0	0.0
Subalpine-alpine wet-site	--	--	--	0.0	0.0	0.0	--	--	--	--	--	--	--	--	--
Montane subshrub	--	--	--	0.1	0.1	0.0	0.0	0.0	0.0	--	--	--	0.9	0.3	-0.5
Subalpine-alpine subshrub	--	--	--	0.0	0.1	0.1*	--	--	--	--	--	--	--	--	--
Cover types-herbland:															
Alpine meadow	0.1	0.2	0.2	0.0	0.1	0.1	--	--	--	--	--	--	0.7	0.8	0.1
Dry meadow	6.2	5.3	-0.9*	0.0	0.1	0.1	0.1	0.0	-0.1	--	--	--	1.7	1.5	-0.2
Colline bunchgrass	3.9	4.6	0.7	0.1	0.2	0.1*	8.3	6.9	-1.4*	--	--	--	1.0	1.2	0.2
Montane bunchgrass	3.4	3.5	0.1	0.7	1.2	0.6*	1.3	1.8	0.5*	0.1	0.2	0.1	1.0	0.7	-0.3*
Subalpine-alpine bunchgrass	--	--	--	0.0	0.0	0.0	--	--	--	--	--	--	--	--	--
Colline exotic grasses-forbs	0.3	1.3	1.0*	0.6	0.8	0.1	0.8	2.3	1.5*	--	--	--	0.9	0.5	-0.4*

Table 29—Historical and current percentage of area for physiognomic types, cover types, and structural classes of 13 ecological reporting units in the midscale assessment of the interior Columbia River basin (continued)

	Change in percentage of area among ERUs														
	Blue Mountains[ab]			Central Idaho Mountains[ab]			Columbia Plateau[ab]			Lower Clark Fork[ab]			Northern Cascades[ab]		
Patch types	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]
	Percent														
Montane exotic grasses-forbs	1.3	1.2	-0.1	0.1	0.2	0.1	0.1	0.3	0.2	0.1	0.1	0.0	0.7	0.9	0.2*
Colline moist-site herbs	0.1	0.0	0.0	0.2	0.2	0.0*	0.1	0.2	0.1	--	--	--	0.0	0.0	0.0
Montane moist-site herbs	0.7	0.5	-0.2*	0.7	0.6	0.0	0.5	0.5	0.1	0.2	0.2	-0.1	0.0	0.0	0.0
Subalpine-alpine moist-site herbs	--	--	--	0.0	0.1	0.1	--	--	--	--	--	--	--	--	--
Wet meadow	0.2	0.0	-0.2*	--	--	--	0.1	0.0	-0.1	0.0	0.0	0.0	0.2	0.1	-0.1
Postfire-grasses	--	--	--	0.1	0.0	-0.1	--	--	--	2.9	0.0	-2.9	--	--	--
Postlogging grasses-forbs	0.0	0.1	0.1*	0.0	0.2	0.2*	0.0	0.0	0.0	0.4	0.9	0.5	0.1	0.4	0.4*
Cover type-agricultural-rural-urban:															
Cropland	2.3	1.8	-0.5*	0.3	0.2	-0.1	18.1	17.9	-0.1	--	--	--	1.7	1.6	-0.1
Pasture	1.0	1.0	0.0	0.1	0.1	0.1	1.1	1.4	0.3	0.4	0.4	0.0	0.3	0.2	-0.2
Urban-rural	0.1	0.1	0.0	0.0	0.3	0.2*	0.6	0.8	0.2	0.0	0.0	0.0	0.1	0.3	0.2*
Cover type-other:															
Bare ground-road	0.0	0.0	0.0	0.0	0.0	0.0	--	--	--	--	--	--	--	--	--
Rock	0.6	0.7	0.1	3.4	3.6	0.1	0.4	0.5	0.1	0.5	0.3	-0.2	4.8	5.1	0.3
Postlogging-bare ground-burned	0.0	0.3	0.6*	0.2	0.7	0.5*	2.8	1.6	-1.2	0.0	1.1	1.1	0.5	1.5	0.9*
Postlogging-bare ground-slumps	0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.1	0.1	--	--	--	1.5	1.3	-0.2
Stream channel-nonvegetated flood plain	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0	-0.2	0.2	0.3	0.1	--	--	--
Water	0.1	0.1	0.0	0.1	0.1	0.0	0.3	0.4	0.1*	0.2	0.1	-0.1	0.8	0.8	0.0
Structural classes-forest:															
Stand initiation	3.9	6.5	2.6*	9.7	5.9	-3.8*	2.3	2.8	0.5	32.7	9.5	-23.3*	9.2	10.4	1.3
Stem exclusion, open canopy	14.3	9.6	-4.7*	18.4	17.7	-0.8	6.7	7.8	1.1	15.7	9.2	-6.5*	13.2	13.2	0.0
Stem exclusion, closed canopy	5.0	5.0	0.0	7.7	8.5	0.8	3.8	3.6	-0.2	10.3	17.6	7.3*	7.6	7.9	0.3
Understory reinitiation	13.6	11.2	-2.4*	16.0	21.4	5.5*	3.1	3.3	0.2	16.4	37.7	21.3*	17.5	19.5	2.0
Young multistory	21.3	29.6	8.2*	18.4	17.1	-1.2	7.3	10.0	2.7*	14.3	17.5	3.2	21.2	22.0	0.8
Old multistory	2.2	1.0	-1.3*	1.4	1.2	-0.3	2.3	1.3	-1.0	0.2	0.5	0.3	5.8	2.7	-3.1*
Old single story	2.7	0.9	-1.7*	1.8	1.7	-0.1	1.1	1.0	-0.1	2.2	2.5	0.4	4.3	2.4	-1.9*
Structural classes-woodland:															
Stand initiation	0.0	0.1	0.0	--	--	--	0.1	0.3	0.2	--	--	--	0.0	0.0	0.0
Stem exclusion	2.4	4.0	1.6*	0.1	0.0	0.0	5.9	10.9	5.0*	--	--	--	0.3	0.6	0.3*
Understory reinitiation	0.3	0.2	-0.1	--	--	--	0.6	1.0	0.3	--	--	--	0.0	0.0	0.0*
Young multistory	--	--	--	--	--	--	0.0	0.0	0.0	--	--	--	--	--	--
Old multistory	0.0	0.0	0.0	--	--	--	0.0	0.0	0.0	--	--	--	0.0	0.0	0.0
Old single story	--	--	--	--	--	--	--	--	--	--	--	--	0.0	0.0	0.0
Structural classes-shrubland:															
Open low-medium	11.0	8.3	-2.7*	12.6	12.0	-0.5	23.4	19.4	-4.1*	0.2	0.1	-0.1	2.0	1.8	-0.2
Closed low-medium	2.3	1.8	-0.4	1.6	1.4	-0.2	6.9	3.3	-3.7*	0.0	0.0	0.0	0.8	0.8	0.0
Open tall	0.5	0.4	0.0	2.8	2.8	0.1	0.9	0.4	-0.6*	2.1	1.2	-0.9	0.0	0.0	0.0*
Closed tall	0.2	0.1	-0.1*	2.7	1.5	-1.2*	0.9	0.4	-0.6	1.0	0.7	-0.3	0.0	0.1	0.0*
Structural classes-herbland:															
Open	6.4	8.5	2.1*	0.9	1.1	0.1	7.4	9.0	1.5*	0.2	0.1	-0.1	2.3	2.4	0.1
Closed	3.2	2.5	-0.7*	1.7	2.2	0.5*	3.8	3.2	-0.5	0.2	0.3	0.2	1.5	1.0	-0.5
Structural classes-other:															
Nonforest-nonrange	11.1	10.0	-1.1*	4.4	5.4	1.1*	23.8	23.2	-0.6	4.7	3.2	-1.5	14.3	15.2	0.9*

Table 29—Historical and current percentage of area for physiognomic types, cover types, and structural classes of 13 ecological reporting units in the midscale assessment of the interior Columbia River basin (continued)

	Change in percentage of area among ERUs														
	Northern Glaciated Mountains[ab]			Northern Great Basin[ab]			Owyhee Uplands[ab]			Snake Headwaters[ab]			Southern Cascades[ab]		
Patch types	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]
	Percent														
Physiognomic types:															
Forest	81.0	80.8	-0.2	7.2	7.3	0.0	0.2	0.2	0.0	74.5	73.8	-0.7	80.5	88.3	7.8
Woodland	0.0	0.0	0.0	15.3	22.2	6.9*	5.5	7.6	2.1*	0.2	0.3	0.1*	0.0	0.4	0.4
Shrubland	3.1	2.5	-0.5	72.8	57.6	-15.2*	88.8	81.0	-7.8*	16.3	13.9	-2.4*	0.5	0.5	0.1
Herbland	7.4	8.1	0.7	3.9	12.2	8.3*	1.0	7.4	6.4*	6.1	8.7	2.6*	0.6	2.7	2.1*
Other[d]	8.5	8.5	0.0	0.8	0.8	0.0	4.5	3.8	-0.6	3.0	3.3	0.4	18.4	8.1	-10.4*
Cover types-forest and woodland:															
Pacific silver fir	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Grand fir-white fir	0.0	1.2	1.2*	--	--	--	--	--	--	--	--	--	5.9	6.5	0.6
Engelmann spruce-subalpine fir	11.5	13.2	1.7*	--	--	--	--	--	--	24.3	31.4	7.1*	0.0	0.2	0.2*
Shasta red fir	--	--	--	--	--	--	--	--	--	--	--	--	0.2	0.4	0.2*
Aspen-cottonwood-willow	0.3	1.9	1.6	8.4	7.7	-0.8	0.2	0.2	0.0	8.8	5.7	-3.1*	0.0	0.0	0.0
Juniper	0.0	0.0	0.0	14.1	21.8	7.7*	5.5	7.5	2.0*	0.2	0.3	0.1*	0.0	0.4	0.4
Western larch	14.8	11.4	-3.4*	--	--	--	--	--	--	--	--	--	0.0	0.0	0.0
Whitebark pine-subalpine larch	0.3	0.2	-0.1	--	--	--	--	--	--	6.9	5.7	-1.3	0.0	0.8	0.8
Lodgepole pine	8.0	8.3	0.3	--	--	--	--	--	--	15.6	11.3	-4.3*	19.4	20.6	1.2
Pinyon pine-juniper	--	--	--	--	--	--	--	--	--	0.0	0.0	0.0	--	--	--
Limber pine	--	--	--	--	--	--	--	--	--	0.7	1.1	0.4*	--	--	--
Sugar pine-western white pine	1.5	0.0	-1.4*	--	--	--	--	--	--	--	--	--	0.3	0.3	0.0
Ponderosa pine	13.4	11.4	-2.0*	--	--	--	--	--	--	0.0	0.0	0.0	22.7	28.1	5.4
Douglas-fir	30.3	30.2	-0.1	--	--	--	0.0	0.0	0.0	18.2	18.6	0.4	1.5	1.7	0.2
Western hemlock with redcedar	0.7	2.8	2.5*	--	--	--	--	--	--	--	--	--	--	--	--
Mountain hemlock	--	--	--	--	--	--	--	--	--	--	--	--	30.5	29.7	-0.8
Cover types-shrubland:															
Colline low-medium	0.1	0.1	0.0	20.0	18.1	-1.8	87.7	79.3	-8.5*	0.1	0.0	-0.1	--	--	--
Montane low-medium	0.0	0.1	0.1*	51.2	37.7	-13.5*	--	--	--	13.0	10.7	-2.3*	--	--	--
Subalpine-alpine low-medium	1.1	0.8	-0.2	0.6	2.0	1.4	--	--	--	0.1	0.3	0.2	--	--	--
Colline mahogany species	0.4	0.0	-0.4*	--	--	--	0.8	1.1	0.4	--	--	--	--	--	--
Montane mahogany species	0.2	0.0	-0.2*	0.4	0.4	0.0	--	--	--	0.0	0.1	0.1	--	--	--
Colline tall	0.7	0.3	-0.4	--	--	--	0.1	0.3	0.2	0.0	0.0	0.0	--	--	--
Montane tall	0.4	0.6	0.2	0.1	0.1	0.0	--	--	--	2.1	2.1	-0.1	--	--	--
Colline wet-site	0.3	0.2	-0.1*	--	--	--	0.3	0.3	-0.1	--	--	--	--	--	--
Montane wet-site	0.1	0.2	0.1*	1.0	0.9	-0.1*	--	--	--	2.8	2.8	0.0	--	--	--
Subalpine-alpine wet-site	0.0	0.0	0.0	--	--	--	--	--	--	--	--	--	--	--	--
Montane subshrub	0.3	0.4	0.1	--	--	--	--	--	--	--	--	--	--	--	--
Subalpine-alpine subshrub	0.0	0.1	0.1*	--	--	--	--	--	--	--	--	--	--	--	--
Russian olive	--	--	--	--	--	--	0.1	0.0	-0.1	--	--	--	--	--	--
Cover types-herbland:															
Alpine meadow	0.0	0.0	0.0	--	--	--	--	--	--	--	--	--	0.1	0.2	0.1
Dry meadow	0.0	0.0	0.0*	--	--	--	--	--	--	--	--	--	0.0	0.1	0.0*
Colline bunchgrass	1.6	0.8	-0.8*	0.0	0.5	0.5	0.2	0.2	0.0	0.0	0.0	0.0	--	--	--
Montane bunchgrass	1.6	1.9	-.2	1.1	5.5	4.5*	--	--	--	2.2	4.3	2.1*	--	--	--
Subalpine-alpine bunchgrass	0.0	0.0	0.0	1.5	0.8	-0.7	--	--	--	0.1	0.3	0.2	--	--	--
Colline exotic grasses-forbs	1.0	1.2	0.2	0.0	2.5	2.5*	0.2	6.2	6.1*	--	--	--	--	--	--

Table 29—Historical and current percentage of area for physiognomic types, cover types, and structural classes of 13 ecological reporting units in the midscale assessment of the interior Columbia River basin (continued)

	Change in percentage of area among ERUs														
	Northern Glaciated Mountains[ab]			Northern Great Basin[ab]			Owyhee Uplands[ab]			Snake Headwaters[ab]			Southern Cascades[ab]		
Patch types	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]
								Percent							
Montane exotic grasses-forbs	0.5	0.7	0.1	0.0	0.0	0.0	--	--	--	0.2	0.7	0.5*	--	--	--
Subalpine-alpine exotic grasses-forbs	--	--	--	--	--	--	--	--	--	0.0	0.1	0.1	--	--	--
Colline moist-site herbs	0.0	0.0	0.0	--	--	--	0.1	0.5	0.4*	--	--	--	--	--	--
Montane moist-site herbs	0.2	0.2	0.0	0.6	1.2	0.6	--	--	--	1.5	1.1	-0.4*	0.0	0.1	0.1
Subalpine-alpine moist-siteherbs	0.0	0.0	0.0	0.1	0.0	-0.1	--	--	--	0.0	0.0	0.0	--	--	--
Wet meadow	0.1	0.1	0.1*	--	--	--	--	--	--	--	--	--	0.5	0.6	0.0
Postlogging grasses-forbs	0.1	0.8	0.7*	--	--	--	--	--	--	0.0	0.1	0.1	0.0	1.6	1.6*
Cover type-agricultural-rural-urban:															
Cropland	3.4	4.3	0.9	--	--	--	1.1	1.4	0.3	0.3	0.1	-0.3	0.2	0.0	-0.1
Pasture	1.4	1.7	0.3*	--	--	--	0.5	0.5	0.0	--	--	--	--	--	--
Urban-rural	0.2	0.3	0.1	--	--	--	--	--	--	--	--	--	0.0	0.3	0.3*
Cover types-other:															
Bare ground	0.0	0.0	0.0	--	--	--	0.0	0.0	0.0	--	--	--	--	--	--
Bare ground-road	--	--	--	--	--	--	0.0	0.0	0.0	0.0	0.1	0.0	--	--	--
Glacier	0.0	0.0	0.0	--	--	--	--	--	--	0.1	0.0	-0.1	--	--	--
Rock	2.3	2.7	0.5*	0.8	0.7	-0.1	2.8	1.9	-0.9	1.7	2.1	-.5	5.2	4.1	-1.1
Postlogging-bare ground-burned	2.2	0.4	-1.7*	--	--	--	0.1	0.1	0.0	0.0	0.0	0.0*	10.1	1.8	-8.4*
Postlogging-bare ground-slumps	0.0	0.0	0.0	--	--	--	--	--	--	0.1	0.0	-0.1	0.4	0.2	-0.2
Stream channel-nonvegetated flood plain	0.1	0.1	0.0*	--	--	--	0.4	0.3	-0.1	0.1	0.1	0.1	0.0	0.0	0.0
Water	0.4	0.5	0.1	0.0	0.0	0.0	0.1	0.1	0.0*	0.9	0.9	0.1*	1.5	1.6	0.1
Structural classes-forest:															
Stand initiation	16.9	9.4	-7.5*	--	--	--	0.0	0.0	0.0	6.4	7.0	0.6	9.1	9.9	0.8
Stem exclusion, open canopy	11.8	11.6	-0.2	6.5	6.0	-0.5	0.0	0.1	0.0	19.1	15.3	-3.8*	12.3	14.3	2.1
Stem exclusion, closed canopy	7.2	12.8	5.6*	0.7	1.3	-0.6	0.0	0.0	0.0	7.9	4.8	-3.1*	0.5	4.8	4.2*
Understory reinitiation	18.4	23.3	4.9*	--	--	--	0.4	1.1	0.7	13.8	12.6	-1.2	10.3	8.7	-1.7
Young multistory	25.5	22.8	-2.7*	--	--	--	0.1	0.1	0.0	22.0	30.9	8.9*	46.0	45.6	-0.4
Old multistory	0.5	0.4	-0.1	--	--	--	--	--	--	3.2	1.8	-1.4*	0.7	1.4	0.7
Old single story	0.7	0.6	-0.1	--	--	--	--	--	--	2.0	1.3	-0.7*	1.6	3.7	2.1
Structural classes-woodland:															
Stand initiation	--	--	--	--	--	--	0.0	0.0	0.0	0.1	0.0	-0.1	--	--	--
Stem exclusion	0.0	0.0	0.0	15.3	22.2	6.9*	5.2	6.5	1.3*	0.1	0.3	0.2	0.0	0.4	0.4
Understory reinitiation	0.0	0.0	0.0	--	--	--	0.3	1.1	0.8	0.0	0.0	0.0	--	--	--
Old multistory	--	--	--	--	--	--	--	--	--	--	--	--	0.0	0.0	0.0
Structural classes-shrubland:															
Open low-medium	1.2	1.1	-0.2	71.8	57.8	-13.9*	85.1	77.2	-7.8*	9.3	7.0	-2.3*	--	--	--
Closed low-medium	0.3	0.5	0.2	--	--	--	2.7	2.1	-0.6	3.9	4.0	0.1	--	--	--
Open tall	1.2	0.8	-0.4	1.2	1.2	0.0	0.8	1.4	0.6*	2.9	2.6	-0.3	--	--	--
Closed tall	0.3	0.4	0.2	0.4	0.2	-0.1	0.3	0.3	0.0	2.1	2.3	0.2	--	--	--
Structural classes-herbland:															
Open	1.4	1.5	0.1	3.4	10.1	6.7*	0.3	6.4	6.1*	1.8	4.2	2.4*	0.0	0.1	0.1
Closed	4.2	3.4	-0.8	0.0	0.5	0.5	0.1	0.5	0.4	2.3	2.3	0.1	--	--	--
Structural classes-other:															
Nonforest-nonrange	10.5	11.6	1.1*	0.8	0.8	0.0	5.0	4.4	-0.6	3.1	3.5	0.3	19.5	11.2	-8.3*

Table 29—Historical and current percentage of area for physiognomic types, cover types, and structural classes of 13 ecological reporting units in the midscale assessment of the interior Columbia River basin (continued)

	Change in percentage of area among ERUs								
	Upper Clark Forks[ab]			Upper Klamath[ab]			Upper Snake[ab]		
Patch types	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]
	Percent								
Physiognomic types:									
Forest	87.2	86.2	-1.0	50.5	47.5	-3.1*	2.4	3.2	0.9*
Woodland	--	--	--	8.4	12.8	4.4*	3.0	2.9	0.0
Shrubland	2.5	2.1	-0.4	21.4	18.8	-2.6	73.8	68.5	-5.3
Herbland	5.5	5.7	0.2	10.6	9.0	-1.6	10.6	9.9	-0.7
Otherd	4.8	6.0	1.2	9.1	12.0	2.9*	10.3	15.4	5.1
Cover types-forest and woodland:									
Grand fir-white fir	0.0	0.1	0.1	7.8	8.1	0.3	--	--	--
Engelmann spruce-subalpine fir	14.2	17.3	3.1*	0.1	0.1	0.0	0.0	0.0	0.0
Shasta red fir	--	--	--	7.8	8.5	0.7	--	--	--
Aspen-cottonwood-willow	0.3	0.3	0.0	0.0	0.1	0.0	0.9	1.0	-.1
Juniper	--	--	--	8.4	12.8	4.4*	2.6	2.5	-0.1
Western larch	2.5	3.0	0.6	0.0	0.1	0.1	--	--	--
Whitebark pine-subalpine larch	4.3	3.5	-0.8*	0.0	0.0	0.0	--	--	--
Lodgepole pine	20.9	19.5	-1.3	1.4	1.7	0.3	0.1	0.2	0.1
Pinyon pine-juniper	--	--	--	--	--	--	0.4	0.5	0.1
Limber pine	0.0	0.4	0.3	--	--	--	--	--	--
Sugar pine-western white pine	--	--	--	0.0	0.0	0.0	--	--	--
Ponderosa pine	12.3	9.5	-2.9*	26.7	23.5	-3.2*	--	--	--
Mountain hemlock	0.0	0.1	0.1	4.7	4.2	-0.5	--	--	--
Cover types-shrubland:									
Colline low-medium	0.8	0.7	-0.1	1.8	2.9	1.1	71.0	62.3	-8.6*
Montane low-medium	0.4	0.7	0.2	18.5	14.9	-3.6*	0.3	0.5	0.2
Subalpine-alpine low-medium	0.2	0.2	-0.1	0.1	0.1	0.0	--	--	--
Colline mahogany species	--	--	--	0.0	0.1	0.1	0.4	0.0	-0.4
Montane mahogany species	0.1	0.0	-0.1*	0.1	0.1	0.0	0.1	0.1	0.0
Colline tall	--	--	--	0.0	0.0	0.0	3.4	5.1	1.6
Montane tall	0.2	0.2	-0.1	0.3	0.4	0.2	0.1	0.4	0.3
Colline wet-site	0.1	0.1	0.0	0.5	0.0	-0.5	0.1	0.1	0.0
Montane wet-site	0.6	0.6	0.0	0.6	0.4	-0.1*	0.0	0.0	0.0
Subalpine-alpine wet-site	0.0	0.0	0.0*	--	--	--	--	--	--
Montane subshrub	0.3	0.0	-0.3*	--	--	--	--	--	--
Subalpine-alpine subshrub	0.0	0.0	0.0	--	--	--	--	--	--
Cover types-herbland:									
Alpine meadow	0.0	0.0	0.0	--	--	--	0.0	0.0	0.0
Dry meadow	--	--	--	0.0	0.0	0.0	--	--	--
Colline bunchgrass	0.3	0.3	-0.1	2.8	1.0	-1.8*	3.7	5.2	1.5*
Montane bunchgrass	3.1	1.8	-1.4*	0.7	0.4	-0.3*	--	--	--
Subalpine-alpine bunchgrass	0.1	0.0	0.0*	--	--	--	--	--	--
Colline exotic grasses-forbs	0.1	0.2	0.0	0.0	0.4	0.4	4.6	4.0	-0.6
Montane exotic grasses-forbs	0.1	0.2	0.1*	0.0	0.0	0.0	--	--	--
Subalpine-alpine exotic grasses-forbs	0.1	0.0	-0.1	--	--	--	--	--	--
Colline moist-site herbs	0.0	0.0	0.0	1.1	0.1	-1.0*	0.1	0.2	0.0
Montane moist-site herbs	0.7	0.7	0.0	0.8	0.7	-0.1	--	--	--
Subalpine-alpine moist-site herbs	0.0	0.3	0.2	--	--	--	--	--	--

Table 29—Historical and current percentage of area for physiognomic types, cover types, and structural classes of 13 ecological reporting units in the midscale assessment of the interior Columbia River basin (continued)

	Change in percentage of area among ERUs								
	Upper Clark Forks[ab]			Upper Klamath[ab]			Upper Snake[ab]		
Patch types	H	C	MD[c]	H	C	MD[c]	H	C	MD[c]
	Percent								
Wet meadow	--	--	--	--	--	--	0.0	0.0	0.0
Post fire-grasses	0.0	0.5	0.4	--	--	--	0.4	0.2	-0.2
Postlogging grasses-forbs	0.0	0.9	0.9*	0.0	0.1	0.1*	--	--	--
Cover types-agricultural-rural-urban:									
Cropland	1.2	1.3	0.1	7.0	10.5	3.5*	2.7	12.1	9.4*
Pasture	0.4	0.4	0.0	4.4	5.3	0.9	0.1	0.2	0.2
Urban-rural	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.2	0.2*
Cover types-other:									
Bare ground-road	0.0	0.0	0.0*	0.0	0.0	0.0*	0.1	0.1	0.0
Rock	2.5	2.4	-0.1	0.2	0.4	0.2	6.8	2.6	-4.1*
Postlogging-bare ground-burned	0.1	1.5	1.4*	0.0	0.4	0.4*	--	--	--
Postlogging-bare ground-slumps	0.0	0.0	0.0	0.0	0.0	0.0	--	--	--
Sand dune	--	--	--	--	--	--	0.5	0.4	-0.1
Stream channel-nonvegetated flood plain	0.1	0.1	0.0	--	--	--	0.1	0.0	-0.1
Water	0.8	0.7	-0.1	2.2	1.4	-0.8	0.1	0.1	0.0
Structural classes-forest:									
Stand initiation	15.9	11.1	-4.8*	1.9	3.6	1.6	0.8	0.3	-0.5*
Stem exclusion, open canopy	18.5	18.2	-0.3	11.3	10.9	-0.4	0.4	1.0	0.6*
Stem exclusion, closed canopy	16.7	21.1	4.4*	1.2	1.6	0.3	0.1	0.1	0.0
Understory reinitiation	15.6	14.0	-1.5	5.6	8.1	2.5	2.5	1.6	-1.0
Young multistory	19.7	21.1	1.3	21.1	16.4	-4.7*	0.6	1.1	0.5
Old multistory	0.6	0.4	-0.2	4.3	5.5	1.2	0.0	0.0	0.0
Old single story	0.2	0.3	0.1	7.4	4.8	-2.6*	0.1	0.0	-0.1
Structural classes-woodland:									
Stand initiation	--	--	--	0.4	1.1	0.7	0.4	0.2	-0.3
Stem exclusion	--	--	--	5.9	7.6	1.6*	0.7	2.0	1.3*
Understory reinitiation	--	--	--	2.0	3.8	1.8*	1.8	0.8	-1.1*
Old multistory	--	--	--	0.0	0.3	0.3	--	--	--
Structural classes-shrubland:									
Open low-medium	1.2	0.8	-0.4	18.5	15.9	-2.6	63.1	57.8	-5.3
Closed low-medium	0.6	0.8	0.2	1.9	2.0	0.1	8.2	5.0	-3.2
Open tall	0.5	0.6	0.2	1.1	0.9	-0.2	3.0	5.2	2.3*
Closed tall	0.5	0.3	-0.3*	0.3	0.2	-0.1	0.7	0.4	-0.4*
Structural classes-herbland:									
Open	1.1	1.3	0.2	3.8	1.4	-2.4*	8.1	9.1	1.0
Closed	3.5	2.1	-1.5*	1.6	1.1	-0.4*	-.7	0.3	-0.4
Structural classes-other:									
Nonforest-nonrange	5.3	7.9	2.6*	13.9	18.2	4.3*	10.8	16.0	5.1

[a] Ecological reporting units of the interior Columbia River basin.

[b] H = historical; C = current; MD = mean difference of pairwise comparisons of historical and current subwatersheds.

[c] * indicates significant difference at $P \leq 0.2$.

[d] Other includes anthropogenic cover types and other nonforest and nonrange types.

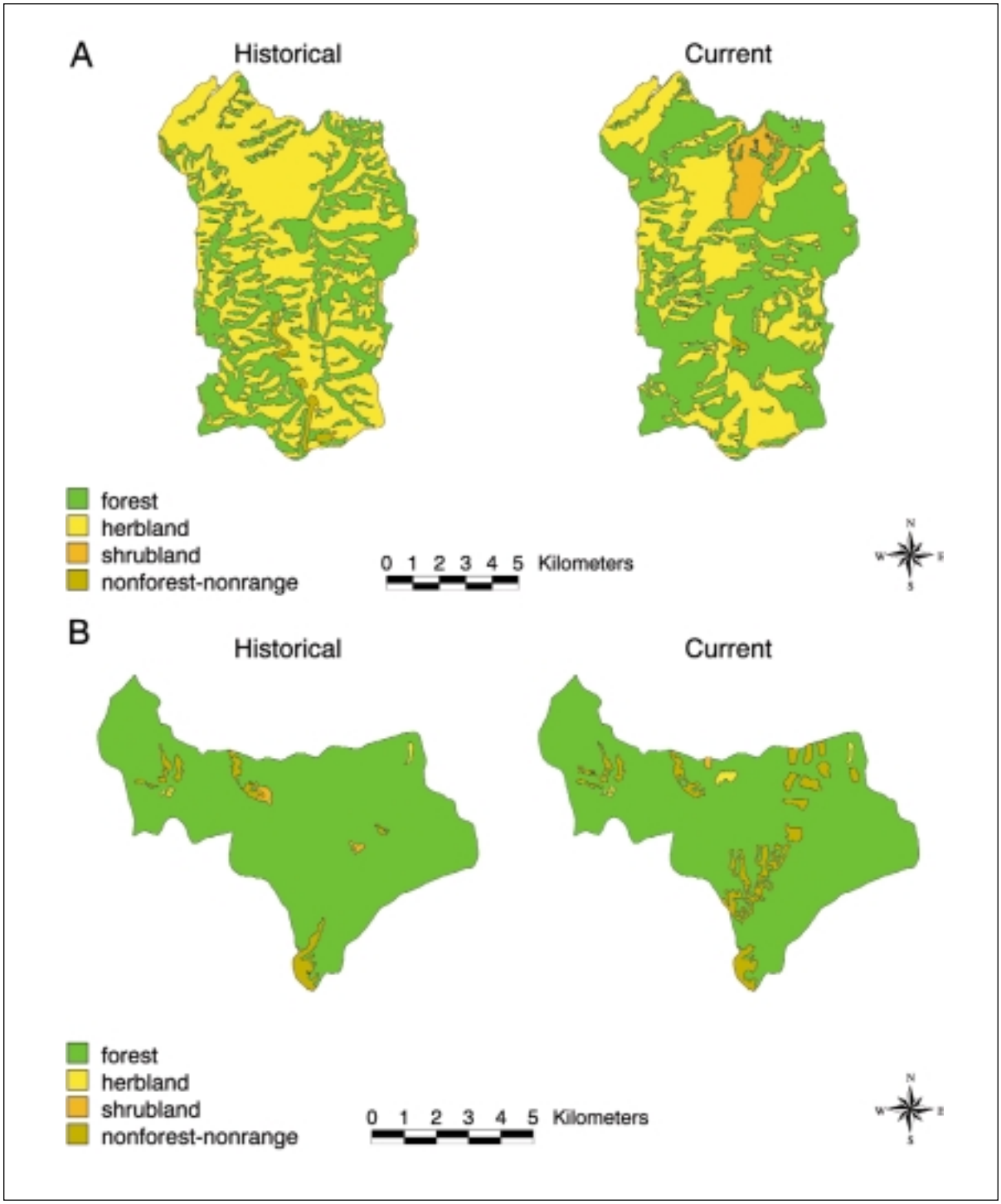

Figure 57—Historical and current maps of physiognomic types: (A) subwatershed 21 in the Lower Grande Ronde subbasin of the Blue Mountains ERU, and (B) subwatershed 0402 in the Upper Klamath subbasin of the Upper Klamath ERU.

Connectivity of forests (as a physiognomic condition) increased in the Central Idaho Mountains and Upper Snake ERUs (appendix 2). The Central Idaho Mountains ERU contains large areas of congressionally or administratively designated wilderness or roadless areas. Across much of the area of this ERU, the primary management activity has been fire prevention and suppression. It is likely that increased connectivity of forests has occurred as a consequence of fire exclusion. Connectivity of forests declined significantly in the Upper Klamath ERU where evidence of timber harvest was widespread.

Woodland area increased in virtually all ERUs that had a significant woodland component in our historical starting point condition, and in some where woodland was apparently a minor component (table 29). Woodland cover increased significantly in the Blue Mountains, Columbia Plateau, Northern Cascades, Northern Great Basin, Owyhee Uplands, Snake Headwaters, and Upper Klamath ERUs, suggesting that fire exclusion and grazing indeed enabled expansion at the expense of declining herblands and shrublands (see Hann and others 1997). Figure 58, A, provides an example of expanded woodland cover in a subwatershed of the Lower Crooked subbasin in the Columbia Plateau ERU.

Perhaps most dramatic of all changes in physiognomic conditions was the across-the-board regional decline in area of shrublands. Shrubland area declined in all ERUs but the Southern Cascades, which had little to begin with (table 29); no ERU exhibited increased shrubland area. Ecologically significant reduction was observed in the Blue Mountains, Central Idaho Mountains, Columbia Plateau, Northern Great Basin, Owyhee Uplands, and Snake Headwaters ERUs. Transition analyses indicated that losses to native shrublands resulted from various factors, including 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 and Snake Headwaters ERUs (see also fig. 58, A).

Herbland area increased significantly in the Central Idaho Mountains, Northern Great Basin, Owyhee Uplands, Snake Headwaters, and Southern Cascades ERUs and declined in no ERU (table 29). This observation is somewhat misleading when viewed superficially: for example, in the Central Idaho Mountains, herbland area apparently increased from an average of 3.2 to 4.5 percent of the ERU (appendix 2), and increases were primarily to colline and montane bunchgrass cover types (table 29); but in the Northern Great Basin, herbland area rose from an average of 3.9 to 12.2 percent of the ERU. In the latter instance, historical shrubland area declined by more than 15 percent of the ERU area. Half of the lost shrubland area is currently occupied by juniper woodland, 4.5 percent supports montane bunchgrass cover, and the remaining 2.5 percent currently supports exotic grass and forb cover.

In the Owyhee Uplands, herbland area rose from 1.0 to 7.4 percent of the ERU, but shrubland area fell from 88.8 to 81.0 percent of the ERU (appendix 2). Most increase in herbland area was the result of expanding colline exotic grass and forb cover with the conversion of shrublands. Figure 58, B, provides an example of increased herbland area in a subwatershed of the Upper Owyhee subbasin in the Owyhee Uplands ERU. Increased herbland area in the Snake Headwaters ERU also was associated with declining shrubland area. Increased herbland and forest area in the Southern Cascades ERU was associated with regrowth of vast dry ponderosa pine forests clearcut early in the 20th century before the historical photos were taken.

Area in “other” nonforest-nonrange types increased significantly in the Central Idaho Mountains, Northern Cascades, and Upper Klamath ERUs and declined in the Southern Cascades ERU for reasons cited immediately above. Figure 59 provides an example of recently increased forest area and reduced nonforest-nonrange area in a subwatershed of the Little Deschutes subbasin in the Southern Cascades ERU. In the Central Idaho Mountains and Northern Cascades ERUs, increased nonforest and nonrange area was the result of expanded

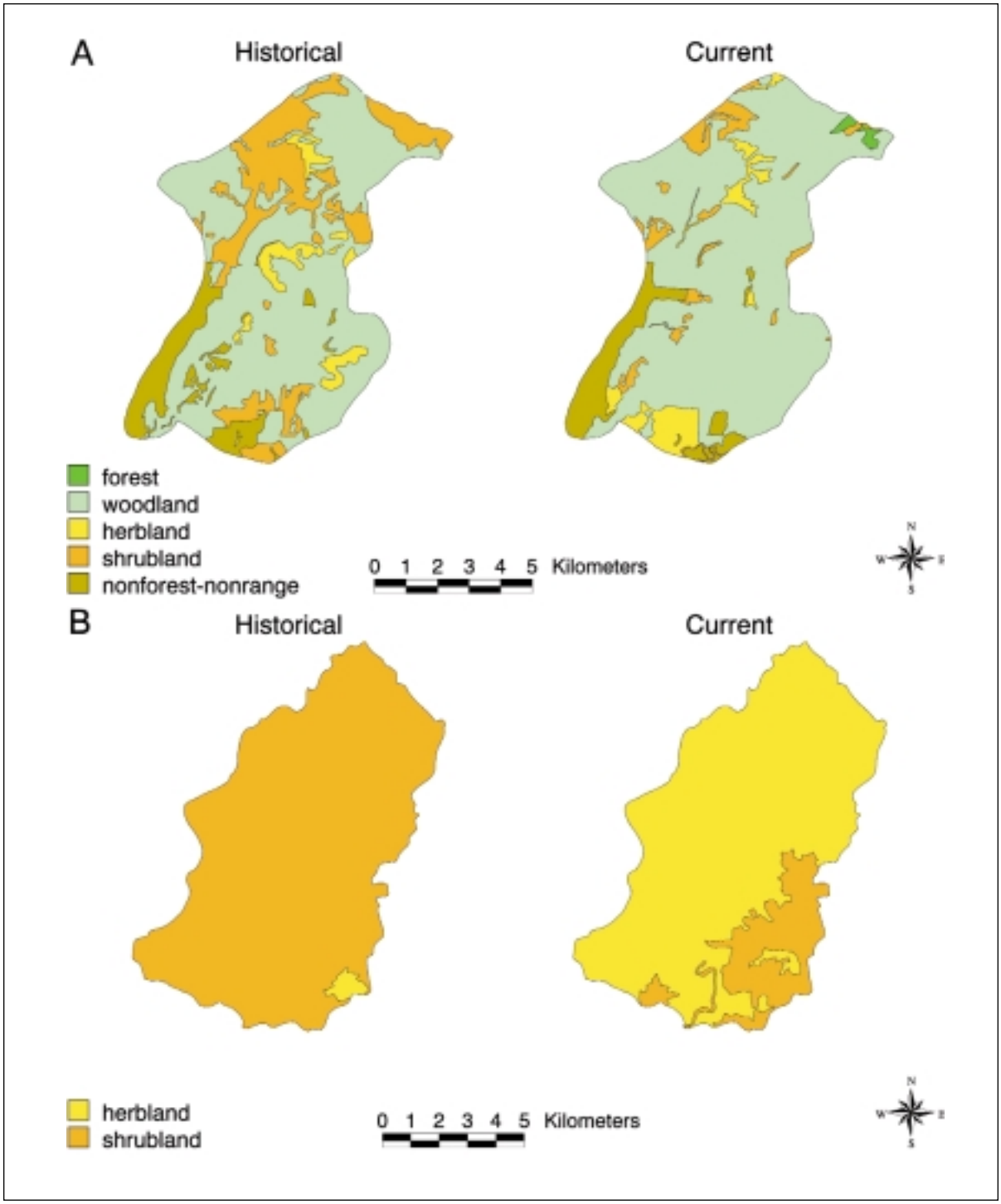

Figure 58—Historical and current maps of physiognomic types: (A) subwatershed o16 in the Lower Crooked subbasin of the Columbia Plateau ERU, and (B) subwatershed 0802 in the Upper Owyhee subbasin of the Owyhee Uplands ERU.

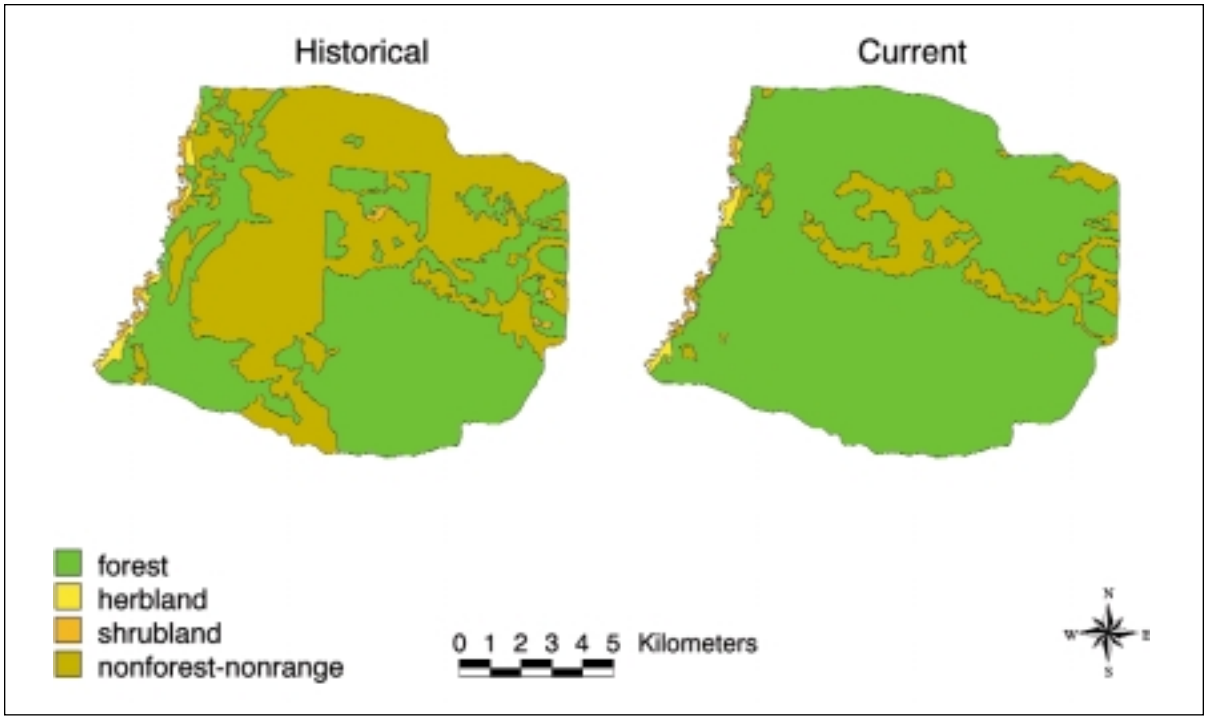

Figure 59—Historical and current maps of physiognomic types in subwatershed 45 in the Little Deschutes subbasin of the Southern Cascades ERU.

urban and rural development and increased bare ground area after logging (appendix 2). In the Upper Klamath ERU, increased nonforest and nonrange area was the result of expanded cropland area and increased bare ground area after logging (fig. 57, B, and table 29).

Forest and woodland cover types—Predicted shifts (Gast and others 1991; Harvey and others 1994, 1995; Hessburg and others 1994; Lehmkuhl and others 1994; O'Laughlin and others 1993; Wickman 1992) from early-seral species (such as ponderosa pine, western larch, lodgepole pine, western white pine, and sugar pine) to late-seral species (such as grand fir, white fir, subalpine fir, Engelmann spruce, western hemlock, and western redcedar) were evident in several ERUs. Of all forested ERUs, the most pronounced shifts from early to late seral cover types occurred in the Northern Glaciated Mountains (table 29). Figure 60 provides an example of declining area in early seral species and increasing area in late seral species cover types in a subwatershed of the Pend Oreille subbasin in the Northern Glaciated Mountains ERU.

Western larch cover declined significantly in the Central Idaho Mountains, Columbia Plateau (fig. 61), and Northern Glaciated Mountains ERUs, and ponderosa pine cover decreased in the Northern Cascades (fig. 62), Northern Glaciated Mountains, Upper Clark Fork, and Upper Klamath ERUs. Figure 61 provides an example of reduced area of western larch cover in a subwatershed of the Palouse subbasin in the Columbia Plateau ERU. Figure 62 provides an example of significantly reduced area of ponderosa pine cover in a subwatershed of the Lower Yakima subbasin in the Northern Cascades ERU. Ponderosa pine cover increased in the Southern Cascades from an average of 22.7 to 28.1 percent of the ERU as a result of regrowth of forests clearcut just prior to the period of our historical photo coverage (for example, see fig. 63, A). Lodgepole pine cover

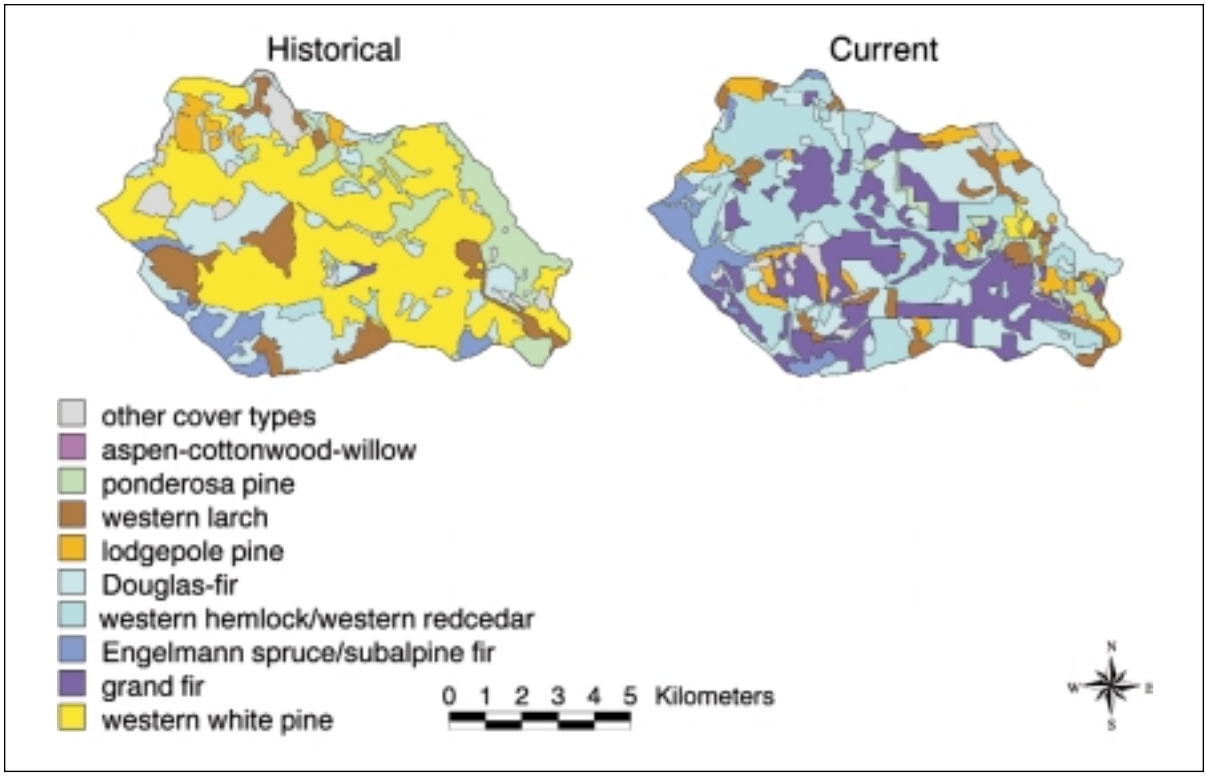

Figure 60—Historical and current maps of forest and woodland cover types in subwatershed 09 in the Pend Oreille subbasin of the Northern Glaciated Mountains ERU.

declined significantly in the Snake Headwaters ERU (see fig. 63, B), and in six other ERUs, but the latter changes were not significant at $P \leq 0.2$.

Western white pine cover decreased significantly in the Northern Glaciated Mountains ERU (fig. 60) as a consequence of blister rust and mountain pine beetle mortality and increased slightly in the Northern Cascades (see fig. 64, A). Whitebark pine-subalpine larch cover declined in the Central Idaho Mountains, Northern Glaciated Mountains, Snake Headwaters (see fig. 63, B), and Upper Clark Fork ERUs, but only the change in the Upper Clark Fork ERU was significant at $P \leq 0.2$; cover increased in the Blue Mountains and Northern Cascades ERUs. Decline in whitebark pine cover likely was the result of ongoing blister rust and mountain pine beetle mortality (Hagle and others 1989, Keane and Arno 1993, Keane and Morgan 1994).

In the Northern and Southern Cascades ERUs, western white pine and sugar pine occurred as relatively minor early seral species in mixed compositions. Large areas of pure type apparently were uncommon. In the Northern Glaciated Mountains ERU, large areas of pure type were relatively more common. Throughout the Inland Northwest, western white pine and sugar pine have long been prized as premium sawtimber species for their rapid growth rate, long straight boles, and superior physical properties and machining characteristics.

Accounts of the earliest logging in the West describe widespread selective harvest of large western white pine throughout northern Idaho, northwest Montana, and the Cascade Range of Oregon and Washington. The extent to which such selective harvest affected five-needle pine reserves in the Northern and Southern Cascades is poorly documented. Additionally, the fungus that causes

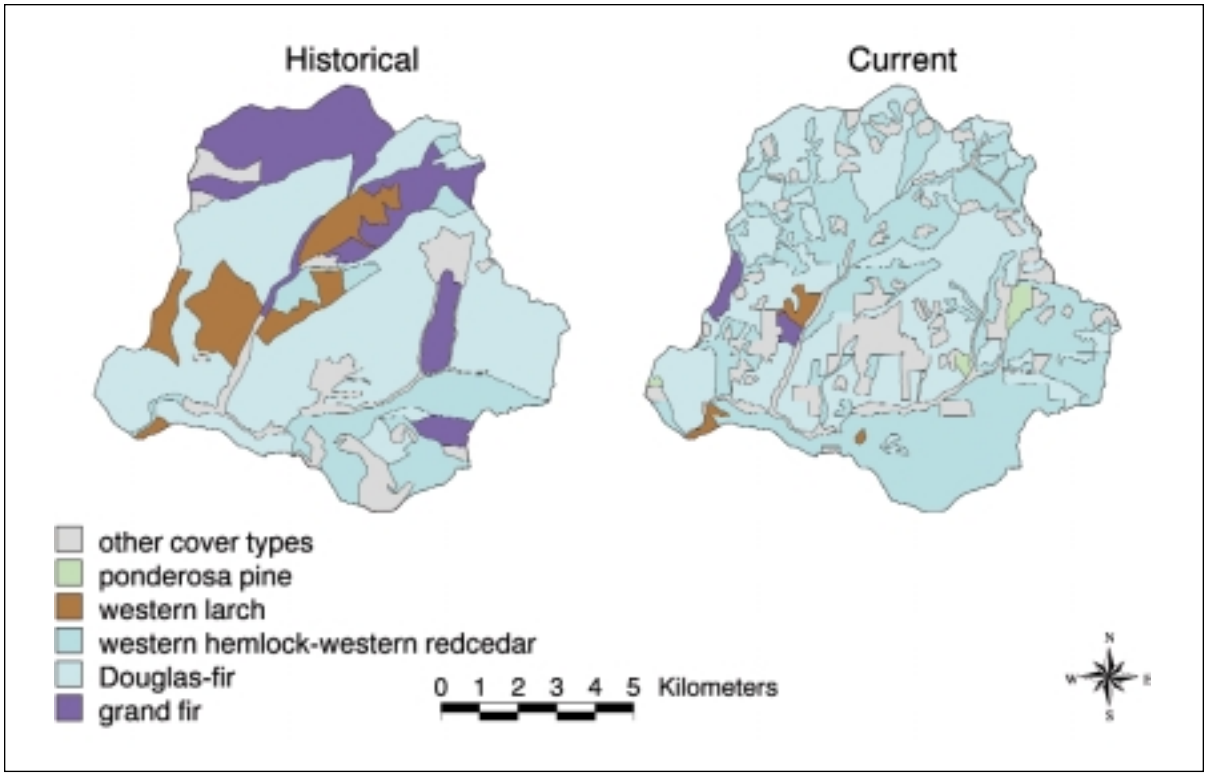

Figure 61—Historical and current maps of forest and woodland cover types in subwatershed 2002 in the Palouse subbasin of the Columbia Plateau ERU.

white pine blister rust was introduced to inland Northwest forests over the last 90 years. Widespread blister rust mortality is prevalent throughout the entire range of western white pine, sugar pine, whitebark pine, and limber pine. For these reasons, our estimates of the historical area of these cover types and other mixed types including these species for the Northern and Southern Cascades, Northern Glaciated Mountains, and Lower Clark Fork ERUs were probably quite conservative. Our results suggest that finer scale plot data and stand reconstructions are needed to improve estimates of historical distribution and abundance of five-needle pines. But focusing only on improved quantitative estimates of decline in reserves of five–needle pines misses the larger point, which our data clearly illustrate: five-needle pines have been decimated by blister rust, timber harvest, and bark beetles, and that has significant ecological and economic consequences for people.

Perhaps greatest among the risks associated with declining five-needle pine reserves is reduced genetic diversity where populations of western white pine and sugar pine have been minimized or eliminated. Across vast areas of the range of western white pine and sugar pine, these species occur as minor or associated early seral species. In many areas, such populations are now extinct or minimized to a remnant. In northern Idaho and northwest Montana, western white pine was a major early seral species across a significant forest area, especially within the western hemlock and western redcedar zones (Cooper and others 1987). As a consequence of blister rust, other coniferous species such as Douglas-fir and grand fir have replaced western white pine in that role, modifying successional trajectories and associated fire, insect, and pathogen ecology.

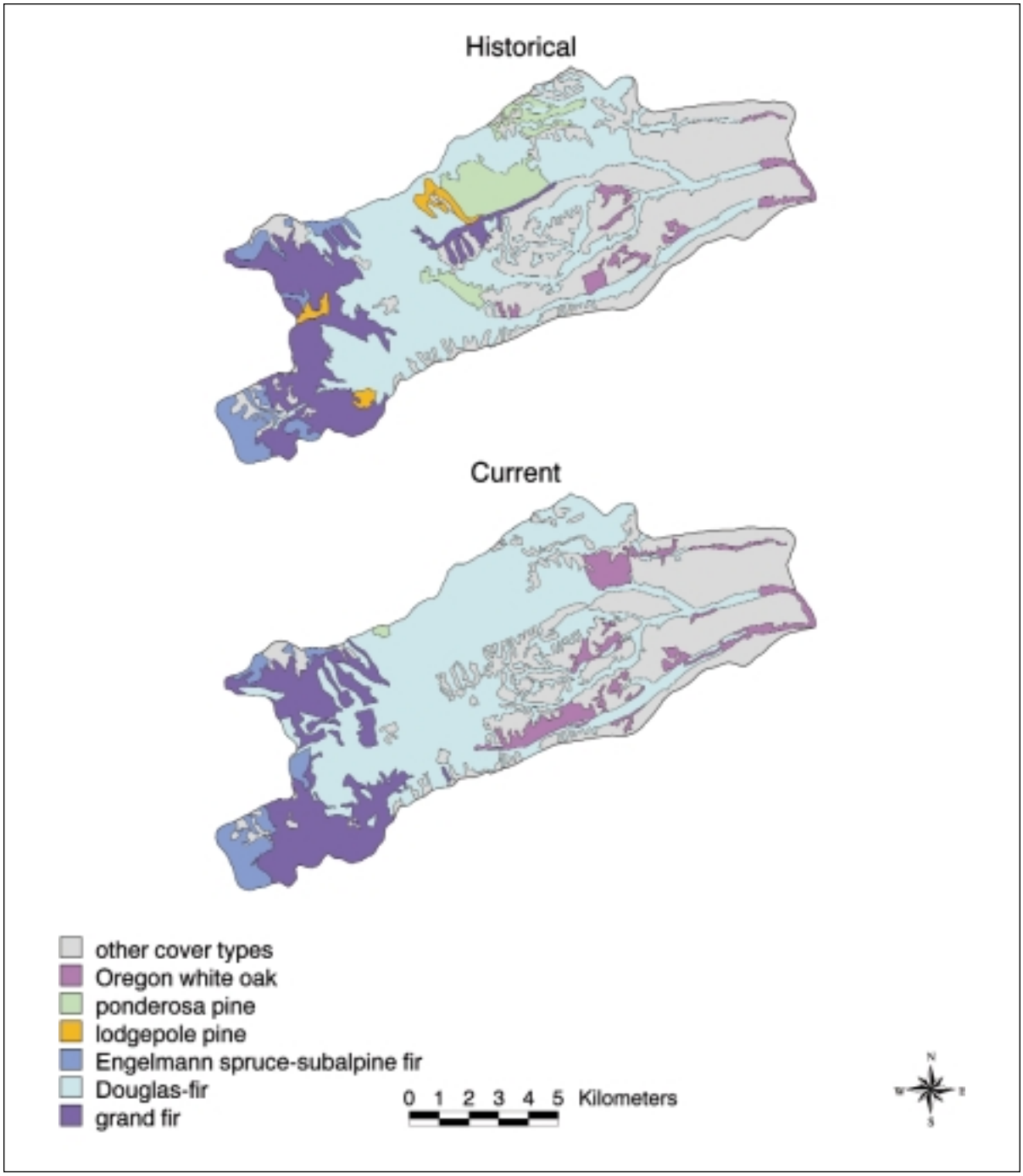

Figure 62—Historical and current maps of forest and woodland cover types in subwatershed 60 in the Lower Yakima subbasin of the Northern Cascades ERU.

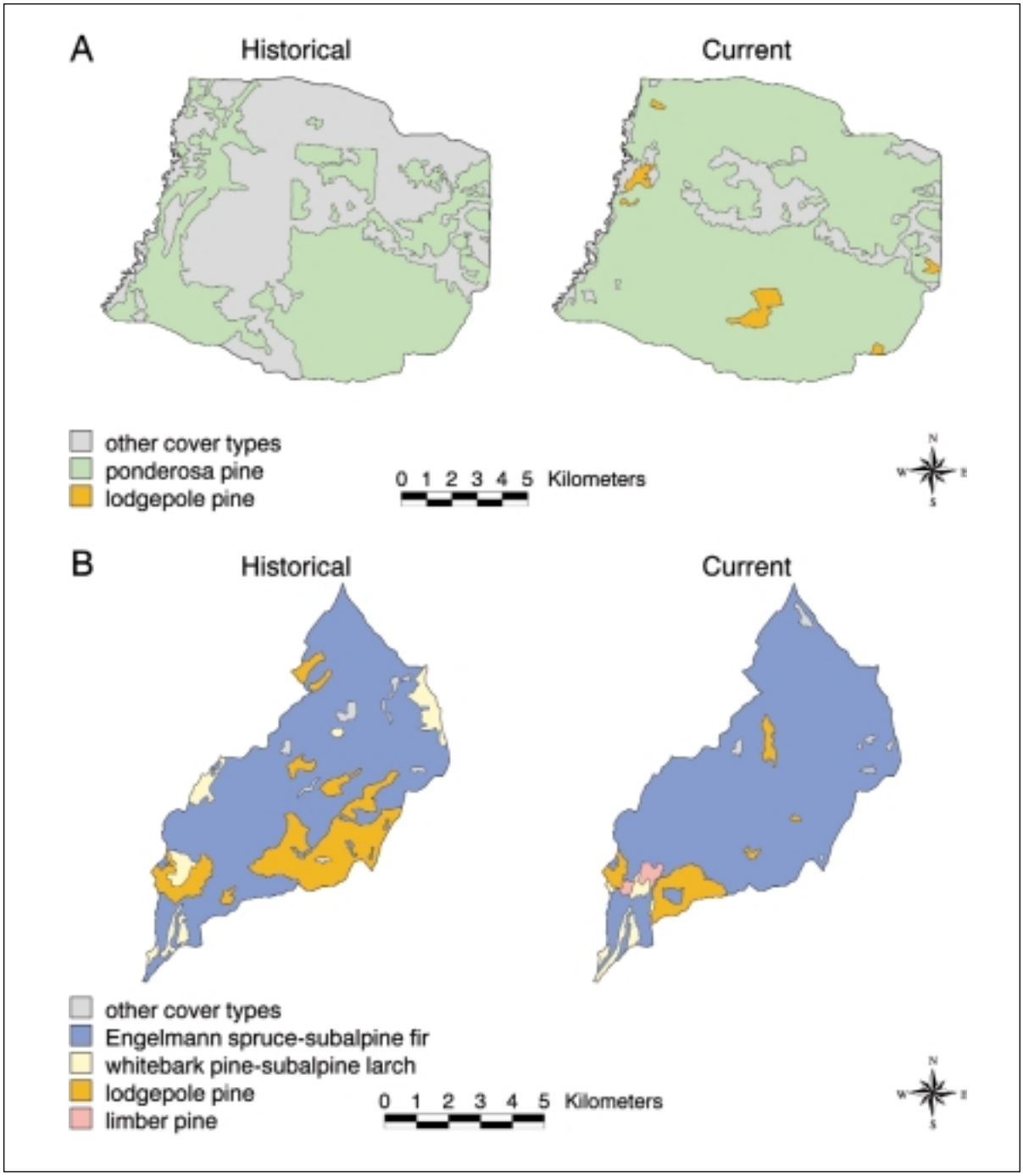

Figure 63—Historical and current maps of forest and woodland cover types: (A) subwatershed 45 in the Little Deschutes subbasin of the Southern Cascades ERU, and (B) subwatershed 0308 in the Snake Headwaters subbasin of the Snake Headwaters ERU.

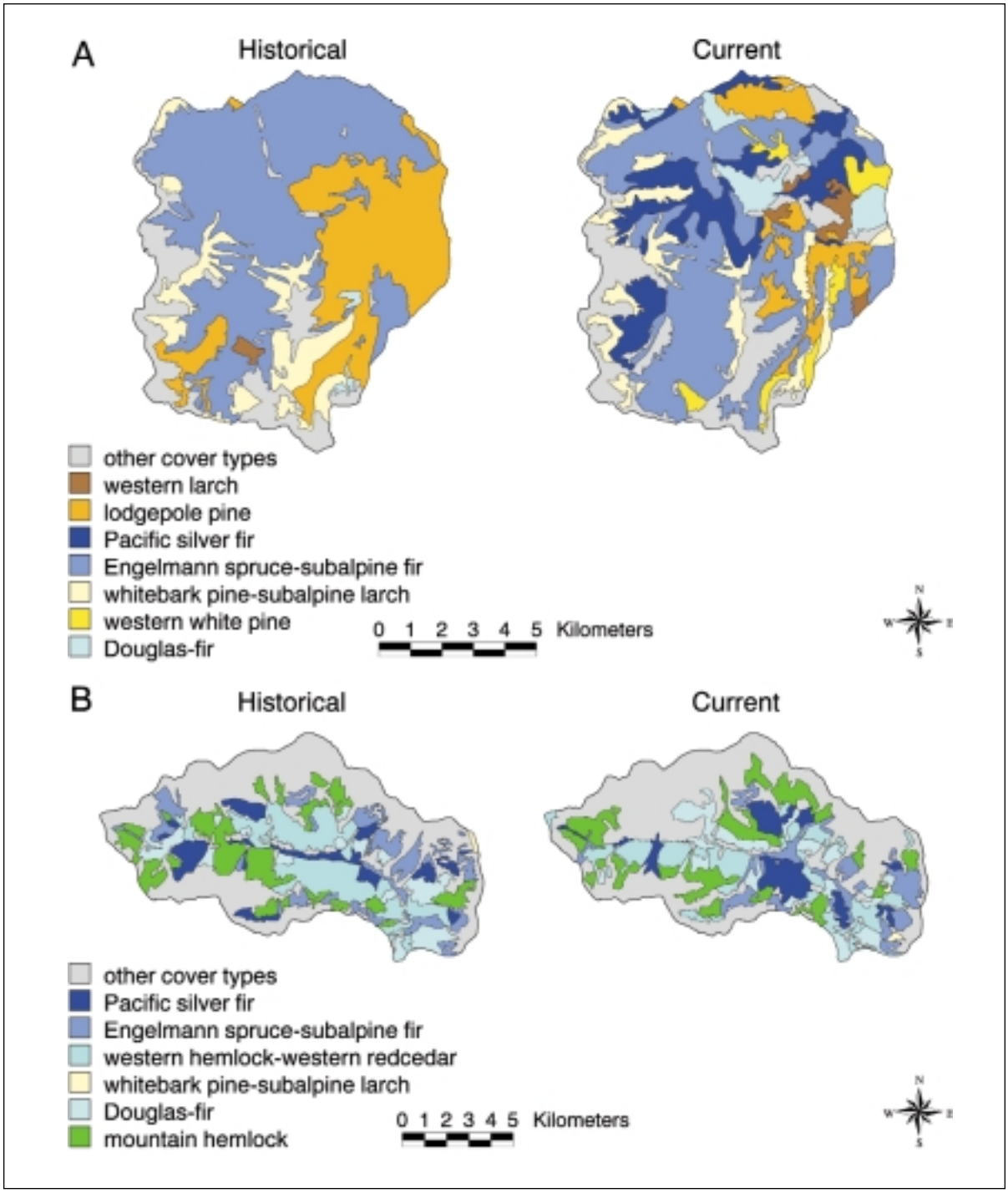

Figure 64—Historical and current maps of forest and woodland cover types: (A) subwatershed 55 in the Methow subbasin of the Northern Cascades ERU, and (B) subwatershed 06 in the Wenatchee subbasin of the Northern Cascades ERU.

Douglas-fir cover increased significantly in the Blue Mountains, Columbia Plateau, and Northern Cascades ERUs (see fig. 62); grand fir-white fir cover increased in the Northern Cascades and Northern Glaciated Mountains (see fig. 60); Pacific silver fir cover increased in the Northern Cascades ERU (see fig. 64, A); Engelmann spruce-subalpine fir cover increased in the Northern Glaciated Mountains, Snake Headwaters (see fig. 63, B), Southern Cascades, and Upper Clark Fork ERUs; and western hemlock-western redcedar cover increased in the Columbia Plateau (fig. 61), and Northern Glaciated Mountains ERUs. Figure 61 provides an example of dramatically increased area of western hemlock-western redcedar cover in a subwatershed of the Palouse subbasin in the Columbia Plateau ERU. Engelmann spruce-subalpine fir cover declined significantly in the Blue Mountains, and Engelmann spruce-subalpine fir (see fig. 64, A) and western hemlock-western redcedar cover decreased in the Northern Cascades. Figure 64, B, provides an example of reduced area and connectivity of western hemlock-western redcedar cover in a subwatershed of the Wenatchee subbasin in the Northern Cascades ERU. Our results suggest that noted increases in shade-tolerant cover types were the direct result of effective fire prevention and suppression programs, selective timber harvest, and fire exclusion and an indirect consequence of the development of extensive road networks, human settlement of interior valleys, movement of Native American Indians onto reservations, and extensive domestic livestock grazing.

Change in area and connectivity of the Douglas-fir cover type should be interpreted with caution because Douglas-fir can be early seral, mid-seral, or late-seral depending on the PVT: Douglas-fir is early seral in the western hemlock, subalpine fir, and Pacific silver fir series, early and mid-seral in the grand fir and white fir series, and late-seral in the Douglas-fir series. Analysis is underway to separate change in area and connectivity of Douglas-fir and other cover types by PVT for each ERU.

Among woodland cover types, juniper cover significantly increased in the Blue Mountains, Columbia Plateau, Northern Great Basin, Owyhee Uplands, Snake Headwaters, and Upper Klamath ERUs (table 29) and did not decrease in any ERU where it was a major cover type. Figure 65 provides an example of substantially increased area of western juniper cover in a subwatershed of the Lower John Day subbasin in the Columbia Plateau ERU. Oregon white oak cover increased in the Northern Cascades ERU (see fig. 62). Fire exclusion and grazing may be causes of the observed increase, but we were unable to directly test this hypothesis.

Shrubland and herbland cover types— Significant reductions in area and connectivity of shrubland cover types were noted in virtually every ERU, but effects were most dramatic where shrublands accounted for more than one-quarter of the land area of an ERU (table 29). The largest reductions in shrub cover types occurred in the Columbia Plateau, Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs. Significant declines in shrub cover types also were observed in the Blue Mountains, Snake Headwaters, and Upper Klamath ERUs. 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 ERU.

Most shrubland cover in the Blue Mountains, Columbia Plateau, Owyhee Uplands, and Upper Snake ERUs resides below lower treeline, and in each case, the most significant losses of shrub cover occurred in these colline settings. Shrublands of the Northern Great Basin, Snake Headwaters, and Upper Klamath primarily occupy montane settings. Cover types of these elevation settings suffered the greatest losses.

In general, herbland cover increased throughout the basin as a result of declining shrubland area, but several important cover type losses were noteworthy. Bunchgrass cover declined significantly in several ERUs, notably the Columbia Plateau, Northern Cascades, Northern Glaciated Mountains, Upper Clark Fork, and Upper Klamath (table 29). Bunchgrass cover increased in the

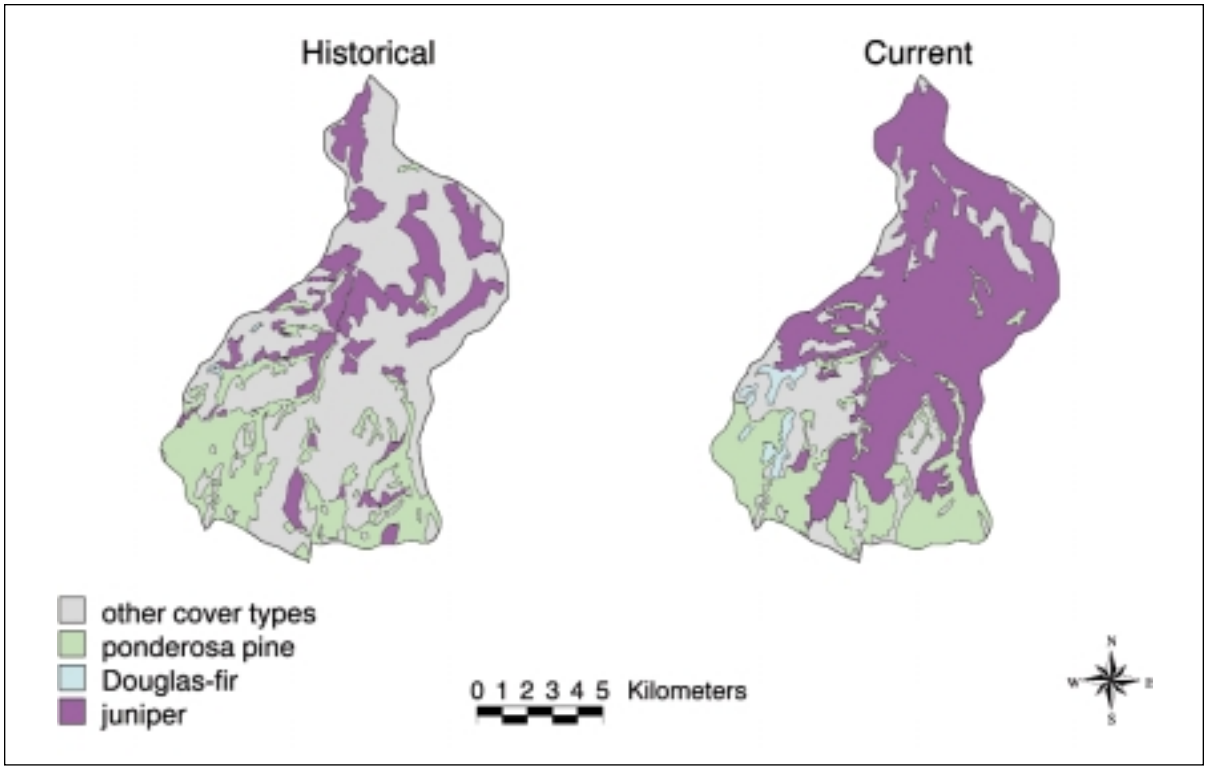

Figure 65—Historical and current maps of forest and woodland cover types in subwatershed 2701 in the Lower John Day subbasin of the Columbia Plateau ERU.

Central Idaho Mountains, Northern Great Basin, Snake Headwaters, and Upper Snake ERUs. Exotic grass and forb cover increased in 9 of 13 ERUs. Significant increases in exotics in either colline or montane settings occurred in the Blue Mountains, Columbia Plateau, Northern Cascades, Northern Great Basin, Owyhee Uplands, Snake Headwaters, and Upper Clark Fork ERUs. Figure 66 provides an example of substantially increased area of exotic grass and forb cover and reduced colline bunchgrass cover in a subwatershed of the Upper Yakima subbasin in the Northern Cascades ERU. Figure 67 provides an example of increased area of exotic grass and forb cover, reduced montane low-medium shrubland cover, and increased montane bunchgrass cover in a subwatershed of the Donner und Blitzen subbasin in the Northern Great Basin ERU. Ecological reporting units most affected by expansion of exotics were, in ascending order, the Columbia Plateau, Northern Great Basin, and Owyhee Uplands. Finally, postlogging grass-forb cover increased in all forested ERUs and increased significantly in all but the Lower Clark Fork and Snake Headwaters ERUs.

Nonforest-nonrange and other anthropogenic cover types—During the course of our aerial photo research, we learned that early historical photographs are rarely available for subwatersheds comprised primarily or entirely of private lands. We were usually able to obtain adequate photographic coverage of a subwatershed when 30 percent or more of the land area was publicly held. As a result, our analysis reflects, at a minimum, change in area and connectivity of nonforest-nonrange and other anthropogenic cover types when they occurred in subwatersheds having substantial public land area. For this reason, we are concerned that some of our results

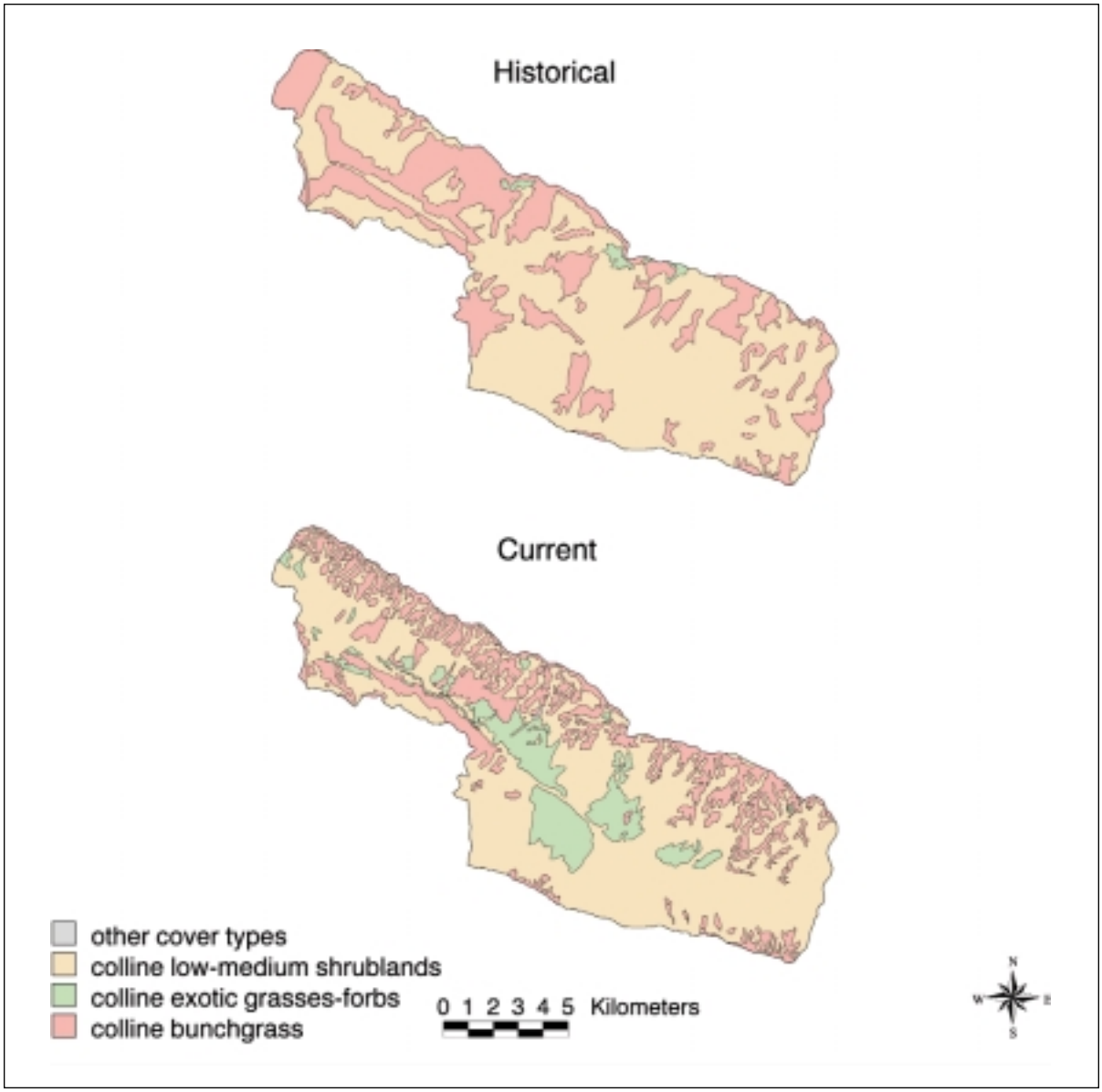

Figure 66—Historical and current maps of shrubland and herbland cover types in subwatershed y3 in the Upper Yakima sub-basin of the Northern Cascades ERU.

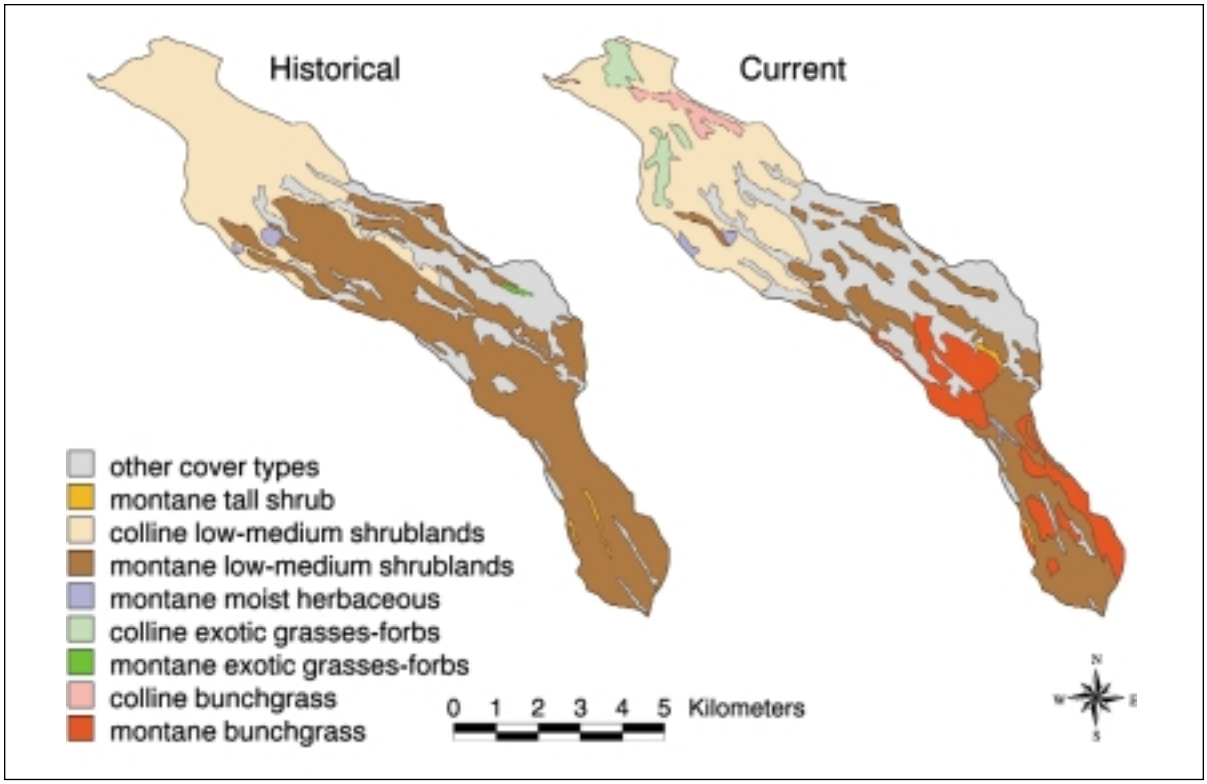

Figure 67—Historical and current maps of shrubland and herbland cover types in subwatershed 0402 in the Donner und Blitzen subbasin of the Northern Great Basin ERU.

may not truly represent changes occurring throughout the total area of each cover type, and they therefore should be interpreted with some caution.

Cropland area increased dramatically in two ERUs: the Upper Klamath and the Upper Snake. In the Upper Klamath, cropland area increased by 50 percent, rising from an average of 7.0 to 10.5 percent of the ERU; in the Upper Snake, cropland area rose more than fourfold (448 percent) from an average of 2.7 to 12.1 percent of the ERU. Figure 68 provides an example of substantially increased cropland area and reduced shrubland and herbland area in a subwatershed of the Lake Walcott subbasin in the Upper Snake ERU. Cropland area declined significantly only in the Blue Mountains. Area in irrigated pastures increased in several ERUs, but only the increase observed in the Northern Glaciated Mountains was significant at $P \leq 0.2$ (see fig. 69). Urban and rural developed area increased in half of the ERUs during the sample period; increase was significant in the Central Idaho Mountains, Northern Cascades, Southern Cascades, and Upper Snake ERUs.

Postlogging of bare ground-burned area increased significantly in several ERUs but, surprisingly, declined in several others. Percentage of area increased in the Blue Mountains, Central Idaho Mountains, Northern Cascades, Snake Headwaters, Upper Clark Fork, and Upper Klamath ERUs, and declined in the Northern Glaciated Mountains and Southern Cascades ERUs. These latter reductions suggested reduced slash burning of postharvest fuels during the sample period and regrowth of forests.

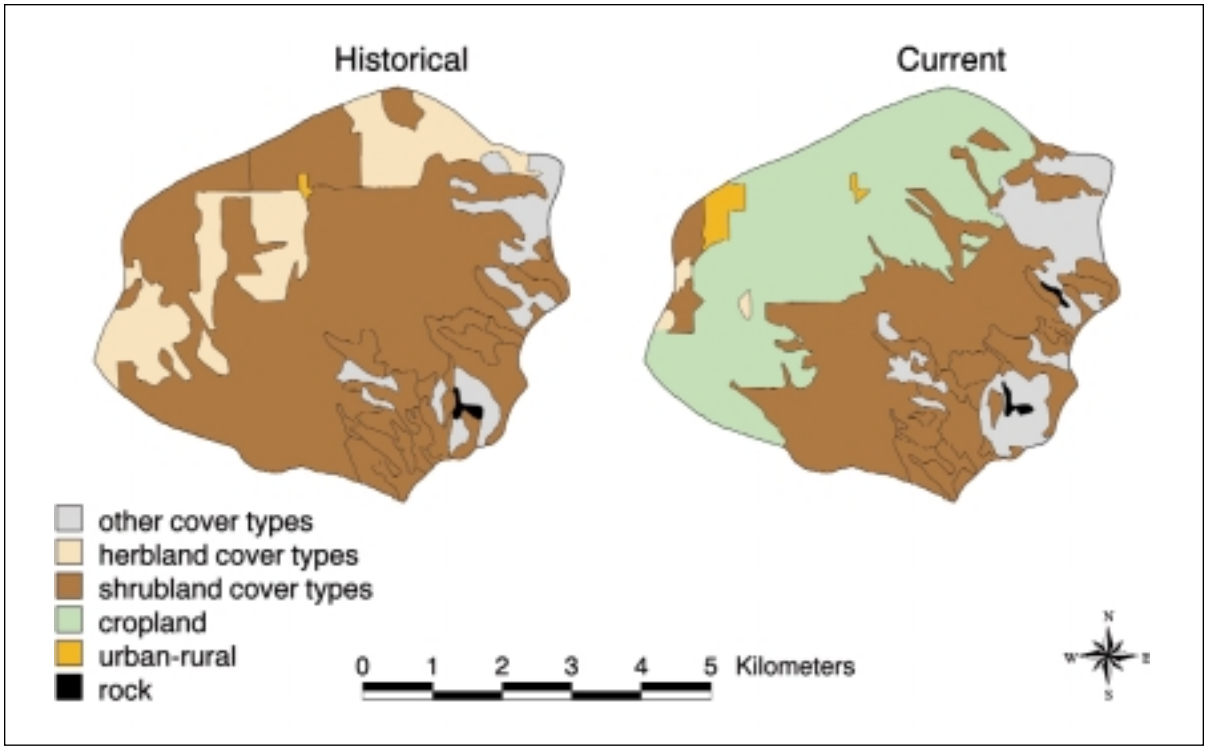

Figure 68—Historical and current maps of shrubland, herbland, and anthropogenic cover types in subwatershed 0203 in the Lake Walcott subbasin of the Upper Snake ERU.

Area of exposed rock declined in seven ERUs, but none so dramatically as the Upper Snake where exposed rock area fell from an average of 6.8 to 2.6 percent of the ERU. Rock areas were not converted directly to cropland as might be superficially indicated in table 29 and appendix 2. Transition analysis in the Upper Snake revealed multiway transitions resulting in declining rock area: areas of exposed rock were overgrown with open-structured low-medium shrubs, but total area in open low-medium shrubs transitioned to open structured seminative and nonnative herblands, colline tall shrublands, and croplands to result in a significant net decline.

Forest and woodland structure—In general, the structure of current forests of sampled ERUs was simpler when compared with historical forests, but causal links with management are difficult to establish because the amount of fire suppression or total timber harvest, for instance, was not directly measurable or quantifiable. Still, structural changes observed were consistent with management activities implicated as primary factors in the overall simplification of the structural complexity of basin forests; namely, timber harvest, fire suppression and exclusion, and grazing (Agee 1994, Everett and others 1994, Gast and others 1991, Hessburg and others 1994, Lehmkuhl and others 1994, O'Laughlin and others 1993).

Area in forest stand-initiation structures declined significantly in four of nine chiefly forested ERUs and increased significantly only in the Blue Mountains (table 29 and appendix 2). Area in stand-initiation structures declined significantly in the Central Idaho Mountains, Lower Clark Fork, Northern Glaciated Mountains, and Upper Clark Fork ERUs. Area in old-forest structures declined in most forested ERUs, but the most significant declines occurred in the Blue Mountains, Northern Cascades, Snake Headwaters, and Upper Klamath ERUs. In general, area in the

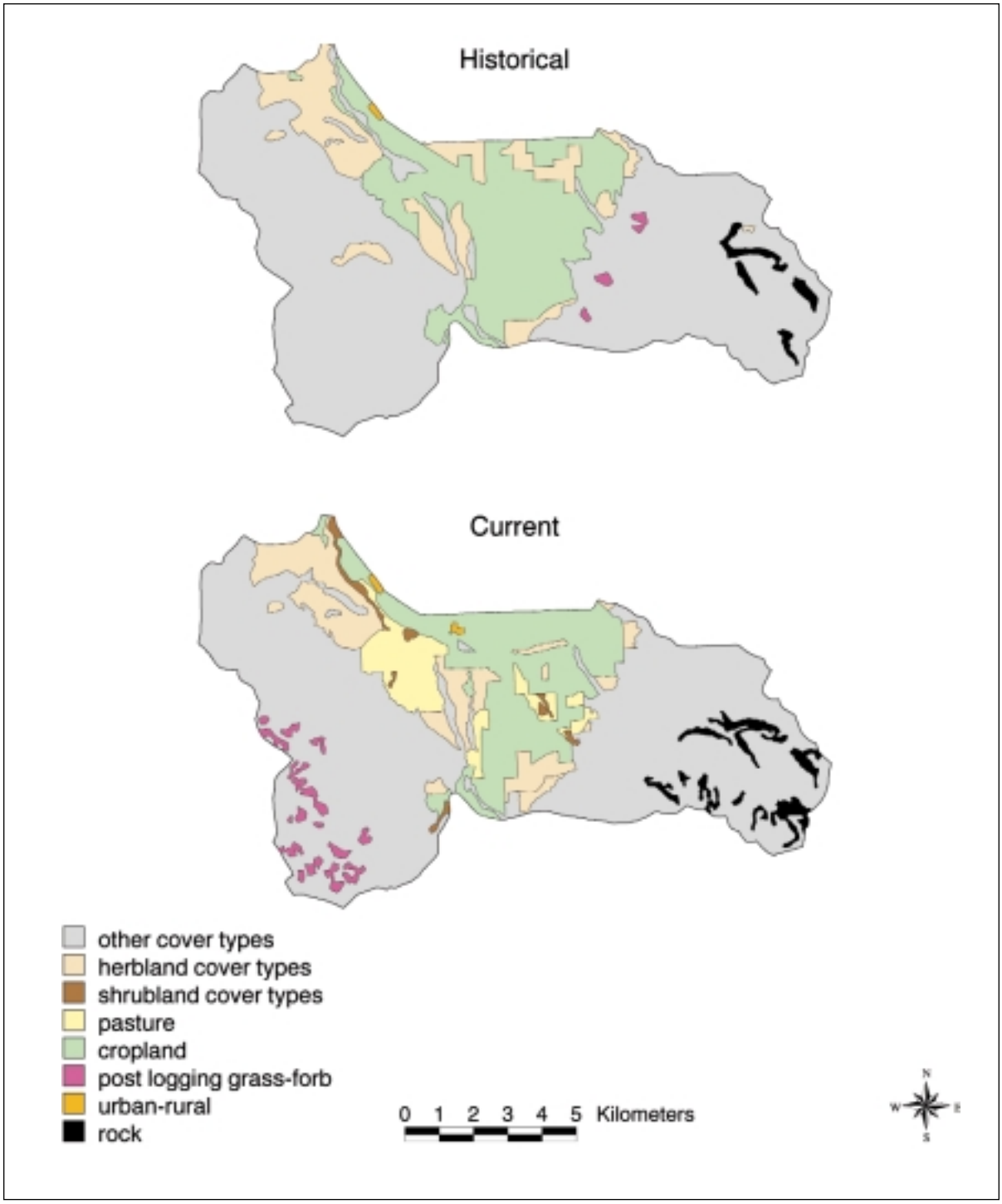

Figure 69—Historical and current maps of shrubland, herbland, and anthropogenic cover types in subwatershed 0701 in the Lower Flathead subbasin of the Northern Glaciated Mountains ERU.

middle-aged, or more precisely, intermediate (not new and not old forest) structural classes (stem exclusion, understory reinitiation, and young multistory) increased in most forested ERUs; the most notable increases occurred in the Blue Mountains, Central Idaho Mountains, Columbia Plateau, Lower Clark Fork, Northern Glaciated Mountains, Snake Headwaters, Southern Cascades, and Upper Clark Fork ERUs. Area in intermediate structural classes actually declined in the Upper Klamath ERU, where most evidence suggested extensive past harvesting.

Blue Mountains ERU—Forests of the Blue Mountains ERU are comprised primarily of dry and mesic potential vegetation types (see fig. 70 and Hann and others 1997). Historical fire regimes resulted in predominantly nonlethal surface fires with frequent (26 to 75 years) to very frequent (0 to 25 years) return intervals (see fig. 71, A and B, and Hann and others 1997). Nearly one-half of historical forest cover was ponderosa pine (table 29 and appendix 2).

Evidence from this analysis suggests that fire exclusion, timber harvest, and grazing each had a pronounced effect on current forest composition and structure. In the historical condition, we would have expected stand-initiation structures to occupy a relatively minor fraction of Blue Mountains 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 an average historical level of 3.9 to 6.5 percent of the ERU in the current condition, most likely as a result of regeneration harvests and removal cuttings (table 27) that occurred during the sample period. Figure 72 provides an example of increased area of stand-initiation structures in a subwatershed of the Lower Grande Ronde subbasin. In our historical vegetation condition, old forests comprised 4.9 percent of the ERU area, or 7.8 percent of the total forest. Selective harvests have diminished that area to a small remnant (fig. 72). Decline in area occupied by medium (40.5 to 63.5 cm d.b.h.) and large (> 63.5 cm d.b.h.) trees was perhaps the single greatest change occurring to all forest structures in the Blue Mountains (tables 21 and 22). In the historical condition, 39.6 percent of the ERU area (63 percent of forest area) was occupied by forest structures comprised of medium and large trees. In the current condition, 27.2 percent of the ERU area (42 percent of the forest) is occupied by forest structures comprised of medium and large trees.

For the Blue Mountains, we predicted that stem exclusion-open canopy structures were common in the historical vegetation coverage because environmental settings that support dry PVTs often are severely moisture limited. Full site occupancy with less than 100 percent crown cover is the result of limited soil moisture, competition from native early seral grasses and shrubs, and frequent surface fires. Area in open-canopy, stem-exclusion structures declined significantly during the sample period. Results suggested that timber harvest, fire exclusion, and domestic livestock grazing activities were associated with the decline (see Oliver and others 1994; Skovlin and Thomas 1995; Wissmar and others 1994a, 1994b). Selective harvest of medium and large trees in a management context of fire control and extensive sheep and cattle 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). Each of these changes was observed. In addition, extensive grazing would minimize flashy fuel cover (Agee 1993, 1994), thereby increasing opportunities for conifer understory development via reduced competition for site resources and reducing the likelihood of surface fires from natural or human-caused ignitions.

Area in understory reinitiation structures declined for similar reasons. Repeated partial cutting in a context of cattle grazing and fire exclusion created increasing area of young multistory structure by encouraging pulsed regeneration and release of shade-tolerant conifers. During the sample period, area in young multistory structures increased from one-third to one-half of the forest area (table 29 and appendix 2). We were surprised to find such an extensive area in young multistory forest structures in our historical coverage. We suggest

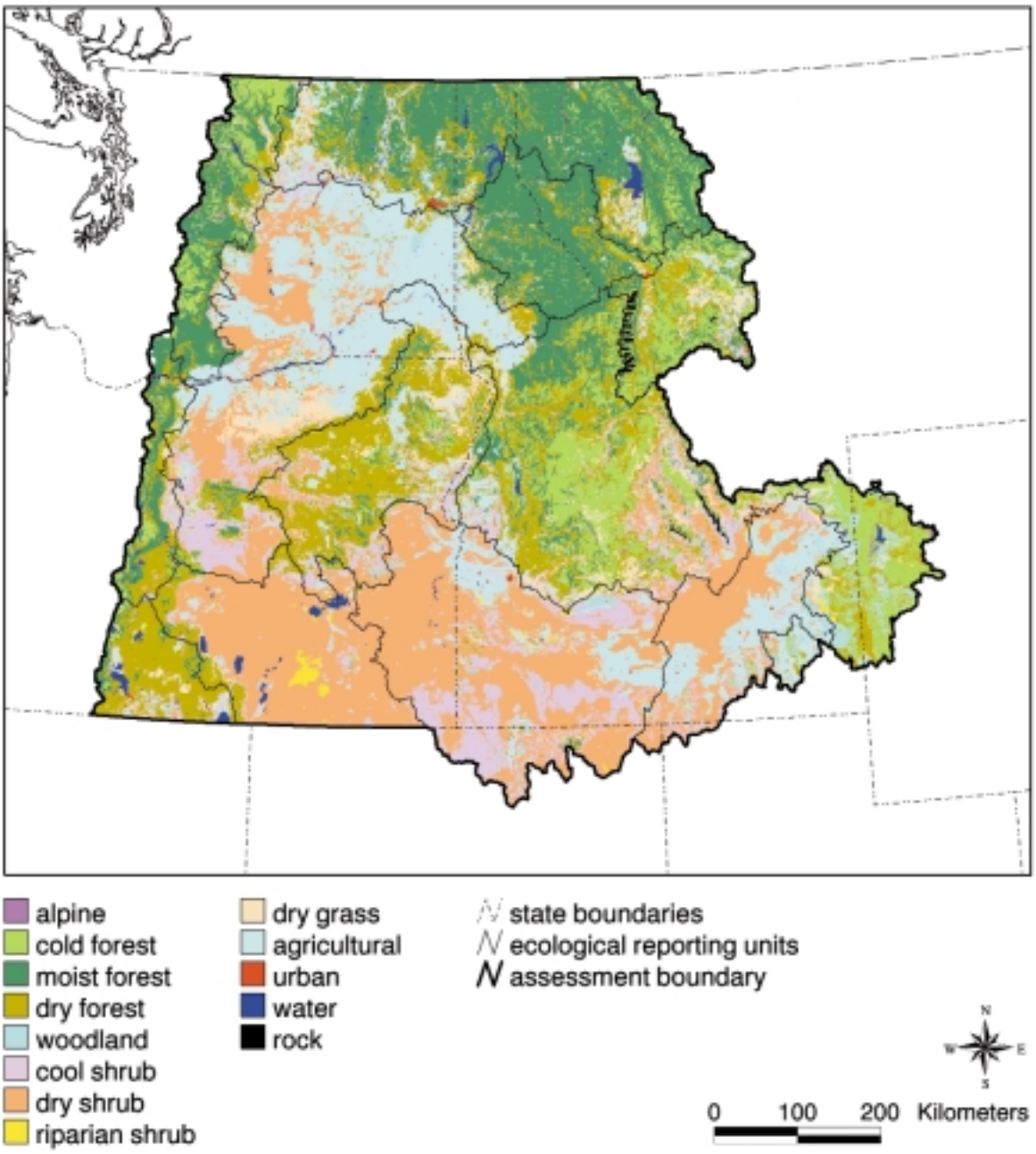

Figure 70—Broadscale (1-km^2 pixels) map of current potential vegetation groups within the interior Columbia River basin assessment boundary. See Hann and others (1997) for map development procedures.