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EFFECTS OF HABITAT FRAGMENTATION ON BIRDS IN THE COASTAL CONIFEROUS FORESTS OF THE PACIFIC NORTHWEST

DAVID A. MANUWAL AND NAOMI J. MANUWAL

Abstract. Few studies have been done in the Pacific Northwest on the effects of habitat fragmentation on birds. Comparisons among studies is difficult because of different study designs and possible regional variation in bird response. Timber harvesting and human settlements have greatly fragmented the once vast amounts of old-growth forests. Forest patches of the Pacific Northwest are typically surrounded by forests of different ages rather than agricultural lands, as is found in much of eastern North America. In Washington, one three-year study showed that overall bird species richness and abundance varied little in a managed coniferous forest despite differing degrees of fragmentation. Some individual species, however, increased or decreased with the amount of clearcut area and other landscape variables. Species associated with open habitats or edges increased, while those associated with forests having a well-developed canopy decreased. There is substantial variation in avian response to landscape variables that characterize watersheds. At the stand level, canopy dwellers and cavity nesting species show the most negative response to increasing levels of canopy reduction, whereas species associated with the ground or shrub layer are least affected. Cowbird parasitism is negligible in the mountains of the Pacific Northwest, but apparently is more widespread in the large valleys such as the Puget Sound lowlands and Oregon's Willamette Valley where more farmland and urban, non-forest environments exist. More studies are needed on fragmentation effects on birds and cowbird parasitism in the region.

Key Words: birds; habitat fragmentation; Pacific Northwest.

Natural forces such as fire, floods, and volcanic eruptions have always created natural heterogeneity, but humans have accelerated fragmentation and caused reductions in suitable habitat in some biomes. In the early days of wildlife management, managers were encouraged to create fragmentation and edges since game species thrived in this environment (Leopold 1933, Allen 1962). With more knowledge of the biology of non-game species, we now know that there are edge-sensitive species that often decline in highly fragmented landscapes (Whitcomb et al. 1981, Ambuel and Temple 1983, Wilcove and Whitcomb 1983). The increased concern over the fate of neotropical migrant passerines has resulted in numerous studies in eastern North America (e.g., Howe 1984, Temple and Cary 1988, Robbins et al. 1989a, Terborgh 1989, Wilcove and Robinson 1990, Freemark and Collins 1992, Robinson 1992, Faaborg et al. 1995, King et al. 1998, Friesen et al. 1999, Rosenberg et al. 1999). Thus, most of the published information on this topic for the United States derives from research done east of the Rocky Mountains.

Based on the many studies of birds in the eastern portions of North America, the principal effects of forest fragmentation on birds are: (1) reduction in patch size and change of patch shape appear to negatively affect area-sensitive species, (2) species especially adapted to living in edge habitats increase, and (3) depending on landscape context, the increase in the amount of edge results in elevated predation rates and increased brood parasitism by the Brown-headed Cowbird (*Molothrus ater*). Few studies have been conducted on the effects of forest fragmentation on birds in the Pacific states. Until recently the emphasis has been on relating bird populations to forest age and structural characteristics (e.g., Manuwal and Huff 1987, Carey et al. 1991, Gilbert and Allwine 1991, Hansen et al. 1991, Manuwal 1991, Ralph et al. 1991; Hansen et al. 1995a,b). Our approach in this paper is to evaluate the effects of forest fragmentation on birds by reviewing published as well as unpublished studies of birds in the coniferous forests of western Washington, western Oregon, and northwestern California, and to present new information from three studies in Washington and Oregon.

RESULTS

CHARACTERISTICS OF FOREST FRAGMENTATION IN THE PACIFIC NORTHWEST

Until Euro-American settlement of the area about 150 years ago, forests in the Pacific Northwest were heterogeneous due to natural events such as wildfires. Approximately 50–60% of the forest land base was old-growth forest at the time of settlement (Franklin and Spies 1984, Booth 1991). Due to timber harvesting and other land use activities, only about 20% of the pre-settlement old-growth Douglas-fir (*Pseudotsuga menziesii*) forests remain (FEMAT 1993). Due to different management goals, the remaining forest is fragmented in a variety of ways (Figs. 1 and 2).

The forests of this region are under federal,

FIGURE 1. Typical forest fragmentation in the Oregon and Washington Cascades, Willamette National Forest, Oregon. Photo courtesy of U.S. Forest Service. Photo taken on 12 July 1987.

state, or private management. Private management, which includes forests managed by timber companies, forests owned by private ownership, and forests on Indian lands, traditionally have been harvested for profit as the major objective. This has resulted in large clearcuts, some over 1,000 ha. These large clearcuts are in various stages of regeneration, and some have been converted into plantations, which typically have a rotation time of 40–60 years (Garmen et al. in press). This does not allow for development of structure associated with mature or old-growth forests (>200 years; FEMAT 1993). These lands are regulated by state laws that mandate a riparian zone buffer, but this is generally narrow and susceptible to edge effects such as windfall and increased insect infestation due to stress on the trees.

The federal lands are managed by agencies with different mandates. The lands administered by the National Park Service, and those designated as wilderness (which in this region are managed by the Forest Service) have a policy of no forest harvesting. Thus, they serve as a refuge for large (>1,000 ha) patches of old-growth forest. These protected forests are often at high elevation, or are bordered by forests that have undergone extensive cutting. The majority of the lands managed by the Forest Service have been harvested by cutting of small patches of

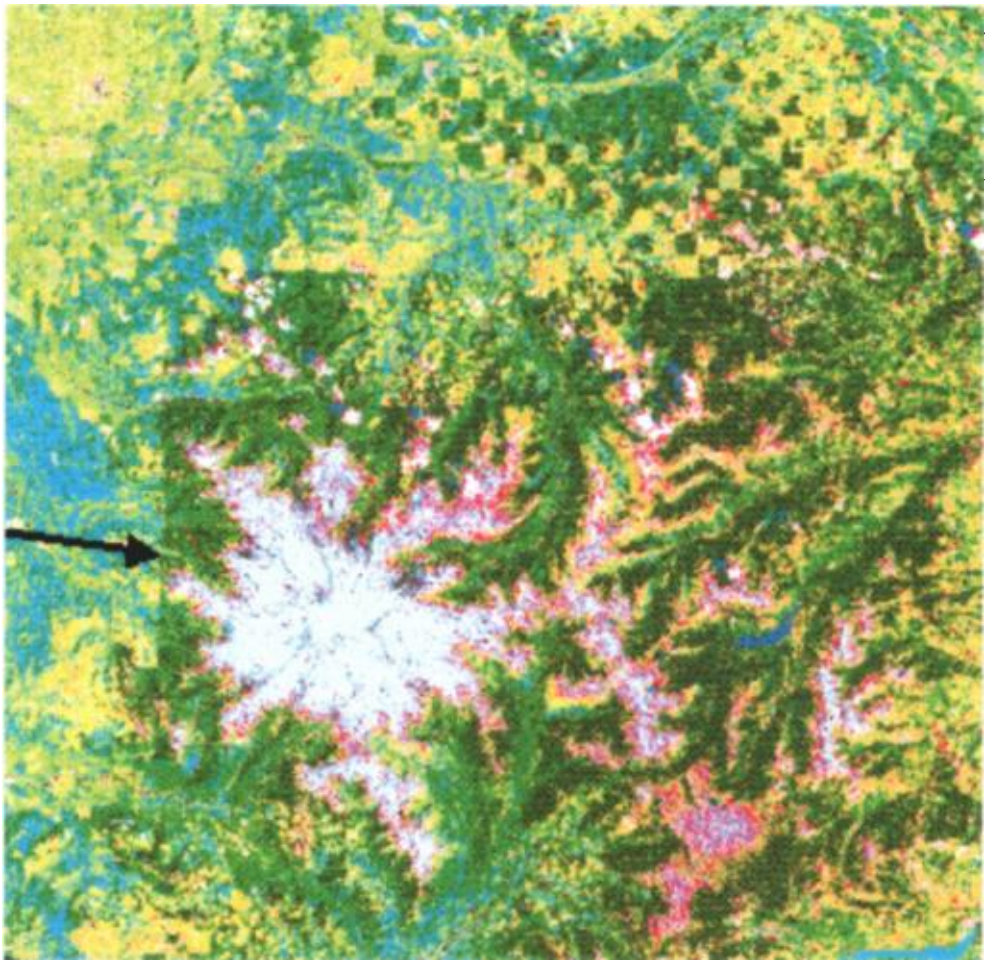

FIGURE 2. Digitized satellite image of western Washington in the Mount Rainier National Park area. Arrow denotes park boundary. Courtesy of C. Grue and K. Dvornich, Washington Gap Analysis.

forest within the old-growth matrix, which has resulted in a checkerboard effect (Franklin and Forman 1987). With time, further cuts between these areas have resulted in different-aged seral forests within the old-growth matrix, causing a loss of large (>1,000 ha) continuous old-growth areas. This technique also results in more edge area than the harvesting practices of the private sector (Spies et al. 1994). The Bureau of Land Management harvesting policy results in mid-sized patches.

The study conducted by Chen et al. (1992) provides insights into the effect of clearcuts on adjacent old-growth forests. They report that these effects include: (1) reduced canopy cover, (2) increased growth rates of Douglas-fir and western hemlock (*Tsuga heterophylla*), (3) elevated rates of tree mortality, and (4) more Douglas-fir and western hemlock seedlings but fewer of Pacific silver fir (*Abies amabilis*; Chen et al. 1992). The effects of clear-cutting on vegetation characteristics of old-growth Douglas-fir forests ranged from 16 to 137 m for variables related to distance from the edge. Thus, some forest patches, especially those less than 10 ha, may be too small to preserve an interior forest environment (Chen 1991).

In Washington, approximately half of the 9,971,625 ha classed as forest lands are administered by federal agencies (McGinnis et al. 1997). Of this, about 11% is wilderness. In Oregon, Spies et al. (1994) clarified the differing rates of harvest in private and public ownership on a 2,589-km^2 study area. Between 1972 and 1988 the closed forest canopy declined from 71% to 58%. In those areas under private ownership, the decrease was from 50% to 28%, for a net loss of 45%. The non-wilderness lands un-

TABLE 2. FRAGSTATS INDICES USED IN LANDSCAPE ANALYSIS OF BIRD SPECIES ABUNDANCE AND COMMUNITY CHARACTERISTICS

Index name (units)	Description[a]
CCAREA (ha)	Total area of clearcuts (3–8 yrs old)
CCED (m/ha)	Total amount of clearcut edge
MAT_AREA (ha)	Total area of mature forest (50–80 yrs old)
PATCHES	Number of patches
ED (m/ha)	Edge density
MNN (m)	Mean nearest neighbor index
SHDI	Shannon's Diversity Index
IJI (percent)	Interspersion and juxtaposition index
CONTAG (percent)	Contagion index

[a] See McGarigal and Marks (1995) for a complete description and definition of each index.

dividual species abundance and six of the nine FRAGSTAT indices. Nine bird species had a positive and eight species had a negative relationship with total clearcut area (CCAREA; Table 3). Virtually all species with a positive response (Table 3) are known to be associated with open, shrubby habitats, so even at the landscape level, these species tend to be most common in a landscape with a large amount of land in clearcuts. All nine bird species typically forage or nest either on the ground or in shrubs and small trees. These species are known as pioneer species and typically are the first ones to colonize recent clearcuts and fire sites. On the other hand, species having negative responses, such as the Winter Wren (*Troglodytes troglodytes*), Golden-crowned Kinglet (*Regulus satrapa*) and Chestnut-backed Chickadee (*Poecile rufescens*), are most often associated with forests with a well-developed canopy, so their response is somewhat predictable.

Eight species were positively correlated with total area of mature forest (MAT_AREA; Table 3). The Pacific-slope Flycatcher (*Empidonax difficilis*), Wilson's Warbler (*Wilsonia pusilla*), Hermit-Townsend's Warbler (either *Dendroica occidentalis* or *D. townsendi* or their hybrids; see Rohwer and Wood 1998), Red-breasted Nuthatch (*Sitta canadensis*), Hairy Woodpecker (*Picoides villosus*), and Evening Grosbeak (*Coccothraustes vespertinus*) all had significant positive responses to the amount of mature forest in the 100 ha circle. The Varied Thrush (*Ixoreus naevius*) and Winter Wren also had negative responses to clearcuts, so these two species may be attracted at the landscape level to more extensive stands of mature forests away from clearcuts.

The Orange-crowned Warbler (*Vermivora celata*) was the only species associated with the amount of clearcut edge. Chestnut-backed Chickadees had a negative association with edge density, indicating that this bird may be an area-sensitive species. The Swainson's Thrush (*Catharus ustulatus*) was negatively associated with an increasing number of habitat patches. Alternatively, the Dark-eyed Junco (*Junco hyemalis*), White-crowned Sparrow (*Zonotrichia leucophrys*), and Spotted Towhee (*Pipilo maculatus*) were positively associated with interspersion and juxtaposition. This seems to suggest that these species are attracted to habitat patchiness.

At the community level, no significant relationships were found between bird species richness and area of clearcuts or area of mature forests in any of the three years of the study. Similarly, no significant relationships were found between the number of bird detections and area of clearcuts or area of mature forests.

Oregon

McGarigal and McComb (1995) investigated bird community response to landscape structure in the central Oregon Coast Range. They sampled 10 landscapes (250–300 ha) in three basins. Each landscape was characterized by the amount of late-seral forest condition and relative fragmentation. Among the many bird species detected, 12 species were strongly associated with late seral forest condition but were also found in other forest conditions. Three species, the Olive-sided Flycatcher (*Contopus borealis*), Red-tailed Hawk (*Buteo jamaicensis*), and Western Wood-Pewee (*Contopus sordidulus*) were associated with habitats where there was a sharp edge between late-seral and early seral forests. Five species were positively associated with patch size: Gray Jay (*Perisoreus canadensis*), Brown Creeper, Winter Wren, Varied Thrush, and Chestnut-backed Chickadee. The following species were more abundant in fragmented landscapes: Red-breasted Sapsucker (*Sphyrapicus ruber*), Western Wood-Pewee, Olive-sided Flycatcher, and Red-tailed Hawk. The Winter Wren showed the most aversion to fragmented landscapes. Meyer et al. (1998) and Franklin and Gutierrez (*this volume*) examine the relationship

TABLE 3. SUMMARY OF RESPONSES OF BIRD SPECIES TO LANDSCAPE METRICS (SEE TABLE 2 FOR DESCRIPTION OF METRICS)

Variable	Bird species	Response (+ or −)	Variable	Bird species	Response
CCAREA	White-crowned Sparrow	+	MAT_AREA	Pacific-slope Flycatcher	+
	McGillivray's warbler	+		Wilson's Warbler	+
	American Goldfinch	+		Hermit/Townsend's Warbler	+
	Bewick's Wren	+		Varied Thrush	+
	Cedar Waxwing	+		Red-breasted Nuthatch	+
	Song Sparrow	+		Hairy Woodpecker	+
	Spotted Towhee	+		Evening Grosbeak	+
	Willow Flycatcher	+		Winter Wren	+
	Common Yellowthroat	+		Swainson's Thrush	−
	Winter Wren	−		American Robin	−
	Dark-eyed Junco	−		Orange-crowned Warbler	−
	Golden-crowned Kinglet	−		Black-headed Grosbeak	−
	Chestnut-backed Chickadee	−		Song Sparrow	−
	Wilson's Warbler	−			
	Hutton's Vireo	−	IJI2	Dark-eyed Junco	+
	Varied Thrush	−		White-crowned Sparrow	+
	Steller's Jay	−		Spotted Towhee	+
CCED	Orange-crowned Warbler	+			
ED	Chestnut-backed Chickadee	−			
PATCHES	Swainson's Thrush	−			

between habitat fragmentation and Spotted Owls (*Strix occidentalis*).

In general, McGarigal and McComb (1995) found a large amount of variation in response to a wide variety of landscape variables. Part of the difficulty in assessing species responses to habitat variables is the scale at which the comparisons was made. Bird abundance was generally greater in more fragmented landscapes. As is true for many other studies, uncommon species or those with large territories such as the Pileated Woodpecker (*Dryocopus pileatus*), are generally undersampled and their relationship with landscape variables could not be determined.

California

Raphael (1984) and Rosenberg and Raphael (1986) assessed the effects of forest fragmentation in Douglas-fir forests of northwestern California by examining point count survey data relative to 10 fragmentation measures at the plot (N = 136), stand (N = 46), and landscape levels. In general, bird species richness increased in fragmented stands. They also found that bird species richness at the plot and stand levels increased with proximity and extent of adjacent clearcut. They found 20 species associated with edges and 20 other species that avoided edges. Among the common species, only the Olive-sided Flycatcher was detected more often on the edge than in the forest interior. Birds showing the most negative responses to forest fragmentation were the Spotted Owl and Pileated Woodpecker, whereas the Sharp-shinned Hawk (*Accipiter striatus*) and Blue Grouse (*Dendragapus obscurus*) showed less population declines in fragmented areas.

LOCAL AND STAND-LEVEL EFFECTS

Washington riparian zones

In an attempt to determine the response of birds to harvest with two different riparian zone buffer widths, eighteen riparian areas within coniferous forests in the western Washington Cascades were studied in 1993, 1995, and 1996 (Pearson and Manuwal 2001). The clear-cuts created adjacent to the sampled riparian zones caused forest fragmentation and created large amounts of edge along the streams. Ten point count stations were visited where birds were counted for 6 min to determine avian relative abundance. Each study site was visited 5–6 times during the nesting season. All sites were studied for one year before harvest and sampled for two years after harvest to evaluate bird response to the buffer widths.

Species richness was higher after harvest in the uplands compared with unharvested controls. Wider buffer widths had higher species richness than did unharvested sites. Predictably, species considered to be edge species, for example Dark-eyed Junco, Song Sparrow (*Melospiza melodia*), and Warbling Vireo (*Vireo gilvus*), increased after harvest. Some species, notably the Golden-crowned Kinglet, decreased significantly after harvest.

Washington and Oregon green tree retention

An experimental on-going study initiated in 1992 in the Pacific Northwest, called Demonstration of Ecosystem Management Options (DEMO), is designed to examine the effects of stand-level green tree retention on ecological attributes of the forest. This was a daunting task because of the scale of the study and public concern over continued cutting on National Forest lands. Details of the study design are given by Aubry et al. (1999). In general, it consists of a randomized block design of six treatments representing varying levels of green-tree retention. Each treatment unit is 13 ha in size and leave-trees (trees remaining after harvest) were either clumped (aggregated) or dispersed through the harvested area. Study sites were only in upland areas.

There are four blocks in Oregon and four in Washington. There is substantial variation in elevation between blocks (210–1,710 m), but usually only about 200–300 m variation within a block (Aubry et al. 1999). Birds were surveyed for two years before experimental retention harvests were made and only two blocks in Washington were surveyed after harvest since the other two blocks had not yet been harvested. An overview of this project and preliminary results of pre-treatment sampling is in Lehmkuhl et al. (1999). We report here some preliminary and geographically limited results of the responses of the following groups of birds: cavity-nesters, forest floor-dwellers, and canopy-dwellers (Table 4). Birds were surveyed by both point counts (4 points, 160 m apart, 6 visits) and territory-mapping (11 species only).

Among the three groups of species, forest floor-dwellers appeared to be less impacted by green-tree removal than the other two groups. Bird populations declined in virtually all conditions after harvest, even the control (100% retention) sites. The spring of 1998 was cold and wet in the Washington Cascades and several species of birds either failed in their first nesting attempt or nested late in the season (D. Manuwal, pers. obs.; M. Leu, pers. obs.). This may account for the lower than expected numbers of birds in control sites. Forest floor birds apparently recognize 75% retention sites as little different from untreated (100%) retention sites since there was no change in populations (Table

TABLE 4. PERCENT CHANGE IN NUMBER OF BIRD TERRITORIES TO GREEN-TREE RETENTION LEVELS AFTER HARVEST IN WASHINGTON IN 1998

Level of retention	Cavity-nesters[a]		Canopy-dwellers[a]		Forest floor-dwellers[a]	
	Butte	Paradise Hills	Butte	Paradise Hills	Butte	Paradise Hills
100% Retention (−0%)[b]	−67	−47	−30	−48	−48	−23
75% Aggregated (−25%)	−73	−73	−76	−73	+29	−29
40% Dispersed (−60%)	−64	−91	−66	−95	−26	−47
40% Aggregated (−60%)	−48	−54	−79	−53	−24	−61
15% Dispersed (−85%)	−80	−82	−93	−89	−48	−18
15% Aggregated (−85%)	−79	−85	−87	−91	−51	−50

[a] Cavity-nesters included: Brown Creeper, Chestnut-backed Chickadee and Red-breasted Nuthatch; canopy-dwellers included: Chestnut-backed Chickadee, Hermit Warbler, and Pacific-slope Flycatcher; forest floor-dwellers were: Dark-eyed Junco, Winter Wren, Varied Thrush.
[b] Amount of canopy reduction.

4). It seems clear that both dispersed and aggregated 15% retention offers little habitat for cavity-nesters and canopy-dwellers. The declines in number were close to the decline in green-tree canopy levels. These results and interpretations are preliminary and additional post-treatment sampling may show more definitive trends in bird community and individual species responses.

The adjustment of bird territory placement relative to retention level and dispersion is an especially interesting aspect of the study. Two examples of how birds adjusted their territories are the Dark-eyed Junco and the Hermit Warbler. The junco was a common bird on the study site, having 3 whole territories and 5 partial territories on a single 40% aggregated retention treatment site (Butte) before harvest. After harvest, there were 3 whole territories and 3 partial territories. Each junco territory contained portions of the retention circles as well as cleared area. This fits with the anticipated response of an edge species. Before harvest, the Hermit Warbler was the most abundant species on the study site; there were 12 complete territories and 5 partial territories on the site. After harvest all but 5 territories disappeared and each of those were located such that there was one territory per circular retention patch. Apparently, the patch contained a sufficient amount of canopy and associated insect prey to allow nesting to occur. We have no data on breeding success but all five males were paired. With additional post-harvest sampling in both Oregon and Washington, stronger conclusions can be drawn from this investigation on the response of birds to fragmentation at the stand level.

OTHER INDIVIDUAL SPECIES STUDIES

There are some studies of the effects of fragmentation on species of conservation concern in the Pacific Northwest such as the Spotted Owl (Meyer et al. 1998, Franklin and Gutierrez *this volume*), which is strongly positively associated with several landscape attributes of late successional forests. There are on-going studies of fragmentation effects on the Marbled Murrelet (*Brachyramphus marmoratus*; Raphael et al. *this volume*). As with studies of eastern bird communities, some species such as the Gray Jay, Brown Creeper, Winter Wren, Varied Thrush, and Chestnut-backed Chickadee tend to decrease with fragmentation and are often associated with late successional forests (Rosenberg and Raphael 1986, Manuwal 1991).

A long-term study of Northern Goshawk (*Accipiter gentilis*) demography, breeding behavior, and habitat selection for foraging and nesting on Washington's Olympic Peninsula was initiated in 1995 by Dan Varland and John Marzluff. Together with graduate students Sean Finn and Tom Bloxton, they are investigating the effects of the local- (forest stand) and landscape-level structure, composition, and spatial arrangement of forests on goshawks. The emphasis of the study is to understand how goshawks respond to habitat loss and fragmentation resulting from timber harvest. The first three years of study concentrated on surveying all known occupied nest areas on the Olympic Peninsula (N = 30) to determine if past habitat modification was correlated with current occupancy. Occupied stands differed from unoccupied ones primarily in having greater canopy closure, although the percentage of the surrounding landscape currently comprised of regenerating forest also was negatively correlated with occupancy. Therefore, fragmentation of the mature forest landscape may reduce occupancy of historical nest sites. However, their current research on the foraging and ranging habits of goshawks in fragmented forests suggest that individual pairs are extremely resilient to forest loss and fragmentation. Goshawks forage primarily in mature forests, but make use of regenerating forests and riparian gaps. They are notably unaffected by habitat loss and fragmentation that occurs while they are occupying an area. The working hy-

TABLE 5. ABUNDANCE OF BROWN-HEADED COWBIRDS IN LOWLAND HABITAT OF WESTERN WASHINGTON FROM BREEDING BIRD SURVEYS (BBS)

BBS route	Name	Years	Mean/year	Population trend[a]
Sea level				
89907	Vashon Island	2	13.0	?
89905	Deception Pass	5	22.6	–
89072	Mukilteo	4	20.5	0
89034	Everett	15	10.5	–
Mean			16.7	
Lowlands, Cascade Foothills				
89111	Carnation	9	19.3	–
89066	Bayview	4	15.8	–
89133	Montesano	11	0.4	0
89078	Pe Ell	3	13.7	0
89059	Raymond	2	7.5	?
Mean			11.3	
Cascades-Low Elevation				
89904	Verlot	6	0.8	–
89902	Cascade River	9	1.2	–
89043	Packwood	19	3.0	–
Mean			1.7	

[a] ? indicates insufficient data; 0 no trend, – decreasing.

pothesis that links these apparently contradictory observations is that specific pairs acclimate and adjust to forest fragmentation in and around their breeding territories, but when these acclimated pairs die, new pairs are less likely to select the formerly occupied habitat for breeding. Lack of continued selection of fragmented habitat by goshawks produces the negative correlation between occupancy and fragmentation, while acclimation to fragmentation allows current territory owners to be unaffected by fragmentation.

BROWN-HEADED COWBIRD PARASITISM

The Brown-headed Cowbird is a relatively recent immigrant to the coastal regions of the Pacific States. It became established in portions of this region only since the 1950s (Rothstein 1994, Morrison and Caldwell *this volume*). In western Washington it may not have become established until a little later since Jewett et al. (1953:592) reported that the cowbird was (referring to the 1940s and 1950s) a "rare migrant and casual winter visitant in western Washington." Since the 1950s, the cowbird has become established as a breeding bird in western Washington but its distribution is clearly restricted to the Puget Trough lowlands. A review of 12 Breeding Bird Survey (BBS) routes in the Puget Sound area indicates that this species is relatively common in the highly fragmented open habitats from sea level up to the foothills of the Cascade Mountains (Table 5). Cowbird abundance decreases with elevation, or at least with a landscape increasingly dominated by coniferous forests. Point count bird surveys in coniferous forests conducted from 1983 to 1998 in the Cascade Mountains at elevations ranging from 300 to 1500 m show that the Brown-headed Cowbird is virtually absent (7 detections out of a total 56,290 bird detections; Table 6) in this landscape even though it is fragmented (Figs. 1 and 2). The cowbirds we detected were in recent clearcuts adjacent to Douglas-fir forests. Factors preventing cowbird colonization of the fragmented coniferous forests in the Washington Cascades are unknown, but it is apparent that cowbird parasitism is not currently impacting potential hosts in the fragmented landscape of the Washington Cascades. Cowbirds are very rare there now but they could become a problem in the future. Cowbirds are relatively common in the Puget Sound Lowlands so parasitism is undoubtedly occurring there, but its extent has not been investigated. The proximity of the presently occupied areas to mountain habitat makes it possible that cowbirds may eventually occupy some of the Cascade and Coast Range montane forests. The effects of predation on songbird communities of the Pacific Northwest is poorly known. A current study by R. Sallabanks is exploring this aspect in managed forests of the Washington Cascades.

CONCLUSIONS

Fragmentation in the mountains of the Pacific Northwest consists of open areas created by clearcut or seed-tree logging in a matrix of for-

TABLE 6. NUMBERS OF BROWN-HEADED COWBIRDS DETECTED IN CONIFEROUS FORESTS OF THE CASCADE MOUNTAINS OF WASHINGTON AND OREGON

Data source[a]	N	Years	Cowbirds detected	Total bird detections
OGWHP	46	2	0	21,962
TFW-RMZ	18	3	0	6,032
TFW-Landscape	24	3	7	20,373
USFS-DEMO-WA	24	2	0	4,446
USFS-DEMO-OR	24	2	0	3,477
Total			7	56,290

[a] Data from point counts within 50 m of points except TFW-RMZ (within 15 m of points). Abbreviations: OGWHP (Manuwal 1991): 12 points, 6 visits, 8 min count duration; 1984, 1985. TFW-RMZ (S. Pearson and D.A. Manuwal, unpubl. data): 10 points, 6 visits, 6 min count duration; 1993, 1995, 1996. TFW-Landscape (Aubry et al. 1997): 12 Points, 6 visits, 8 min count duration, 1993, 1994, 1995. USFS-DEMO-WA (D.A. Manuwal unpubl. data): 4 stations, 6 visits, 8 min count duration; 1995, 1996. USFS-DEMO-OR (D.A. Manuwal unpubl. data): 4 stations, 6 visits, 8 min count duration; 1995, 1996.

ests of various ages. This pattern differs from many areas of eastern North America where forests are located near or adjacent to agricultural lands or human settlements. In the Pacific Northwest, fragmentation appears to be most extensive on private commercial timberlands compared with national forests. The Puget Sound Lowlands have some areas of agriculture, mixed with patches of forests, but this region has not been adequately studied.

The effects of forest fragmentation are not well documented in the Pacific Northwest compared with the many studies in eastern North America [e.g., those cited in Hagan and Johnston (1992) and Martin and Finch (1995)]. Nevertheless, some patterns seem to be emerging from recent studies. Species richness seems to increase in highly fragmented landscapes, chiefly because of the colonization of edge species, which often nest or forage in open, shrubby habitats. However, interior forest birds may be declining under these conditions. The identification of specific landscape variables responsible for this has been difficult to determine, perhaps because birds such as the Winter Wren and Hermit Warbler, which have small territories, respond to stand-level factors rather than large scale ones. There are no long term studies in the Pacific Northwest so we have no information on how fragmentation affects bird abundance. Short-term investigations indicate that some species increase while others decrease with fragmentation, a pattern also observed in the eastern United States.

Brood parasitism and predation have been shown to be a major concern in the fragmented environments of eastern North America (e.g., Robinson et al. 1995b), but there is no evidence that parasitism is an important factor in the coastal mountains of the Pacific Northwest. However, this could become a problem as more forested land is cleared and converted to more open habitat.

Coniferous forests in the Pacific Northwest are naturally heterogeneous because of the effects of fire, wind-throw, floods, and volcanic eruptions. Compared with habitat fragmentation in much of eastern North America, fragmentation in the mountains of the Pacific Northwest is fundamentally different in that forest patches are not surrounded by agricultural land or areas dominated by human development. Instead, forest patches are surrounded by other forest patches of different ages. Late successional forest patches remaining after timber harvesting have become smaller in recent decades and are less suitable for area-sensitive bird species than larger patches. Cowbird brood parasitism is not common in the mountains but does occur in lowland habitats. It is clear that much more research is needed in the Pacific Northwest to determine relationships between birds and forest fragmentation.

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