

**Assemblage Structure of Riparian Birds and Frogs along
Environmental Gradients in Two Valleys of
Southern British Columbia**

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Abstract

Riparian vertebrates, in particular birds and spotted frogs (*Rana pretiosa*) were surveyed in two river valleys, Thompson River drainage, in the southern interior of British Columbia in the fall, 1994. The goal was to assess potential effects of agricultural deforestation on riparian - wildlife diversity, species composition and guild structure. Passerine songbirds dominated all spatial samples, and avifauna were more similar to those in developed habitats than in old-growth, coniferous forests of southern British Columbia. The valley with the more uniform stream gradient showed more longitudinal similarity in vertebrate assemblages. Stream reaches with differing intactness of riparian vegetation differed in bird-species composition and spotted frog densities, reflecting the presence of five habitat-use guilds. Species diversity was similar across reaches with differing vegetation types, although forested habitats had the lowest values. Cavity-nesting bird and spotted frog abundance together with agricultural-urban indicators and diversity indices appear more useful than abundance of riparian species and avifaunal-species richness as indicators for deforestation impact. Overall, results indicate that avifaunal diversity is enhanced by riparian-floral diversity in the dry interior ecosystems of southern British Columbia.

Résumé

Les vertébrés riverains, en particulier les oiseaux et les grenouilles maculées (*Rana pretiosa*) ont été étudiés dans les vallées de deux cours d'eau du bassin versant de la rivière Thompson, de l'intérieur méridional de la Colombie-Britannique, à l'automne de 1994. Le but visé était l'évaluation des effets potentiels du déboisement pour l'agriculture sur la diversité de la faune, sur la variété des espèces et sur la structure de la guildes en bordure des cours d'eau. Les passerins chanteurs étaient les plus abondants dans tous les échantillons et l'avifaune était davantage similaire à celle des habitats des zones aménagées qu'à celle des forêts de vieux peuplements de conifères de la Colombie-Britannique méridionale. La vallée du cours d'eau présentant la pente la plus uniforme offrait longitudinalement une plus grande similitude quant aux communautés de vertébrés. La variété des espèces d'oiseaux et la densité des grenouilles maculées sur des tronçons des cours d'eau variaient selon le caractère plus ou moins intact de la végétation riveraine, ce qui reflète la présence de cinq guildes d'utilisateurs de l'habitat. La diversité des espèces était similaire le long de tronçons présentant des types de végétation différents, bien que les habitats boisés aient présenté les valeurs les plus faibles. L'abondance des oiseaux nichant dans des cavités et des grenouilles maculées ainsi que les indicateurs agriculture-urbanisation et les indices de diversité semblent plus utiles que l'abondance des espèces riveraines et la richesse des espèces avifaunistiques à titre d'indicateurs de l'incidence du déboisement. Dans l'ensemble, les résultats indiquent que la diversité de l'avifaune est améliorée par la diversité de la flore riveraine dans les écosystèmes secs de l'intérieur méridional de la Colombie-Britannique.

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1.0 Introduction

Riverine ecosystems in the Pacific Northwest (PNW) (Raedeke 1988; Morgan and Lashmar 1993), other areas of North America (Pringle 1972; Thomas 1978; Brinson et al. 1981; Knopf et al. 1988; Knopf and Samson 1994), and other continents (Amos 1981; Decamps et al. 1990) are well-known for harboring a relatively high density and diversity of vertebrates in both aquatic and riparian habitats. The enriching effect of river sediments and seasonally fluctuating water levels enhance floodplain-floral productivity (Mitsch and Gosselink 1993; Vadas and Weigmann 1993) via abundant water, food, cover, and breeding habitat for migratory and resident wildlife (Thomas et al. 1979; Brinson et al. 1981; Hobbs and Halbach 1981; Kauffman and Krueger 1984; Raedeke 1988). Riparian-vertebrate diversity in PNW is higher in downstream areas, where water conditions are favorable (deep and stable) and floodplain vegetation is well-developed (Raedeke 1988; Morgan and Lashmar 1993).

Destruction of floodplain forests has caused heavy declines in the density, diversity, and species composition of riparian vertebrates (Brinson et al. 1981; Kauffman and Krueger 1984; Knopf et al. 1988). Riparian damage is particularly severe in larger, lowland streams in North America, which have wider riparian zones and harbor a greater diversity of riparian wildlife, including reptiles, large mammals, and birds (Erskine 1977; Raedeke 1988; Gosselink et al. 1990). Taxa with greater life-history needs for trees (many birds) or moisture (semi-aquatic herpetofauna) are more vulnerable than most small mammals and terrestrial reptiles to riparian deforestation (Geier and Best 1980; Stauffer and Best 1980; Szaro and Rinne 1988; Orians 1992; Wigley and Roberts 1994). Amphibians are especially sensitive because of their permeable skins and dependence on both terrestrial and aquatic habitats (Blaustein and Wake 1990; Wyman 1990; Bishop and Petit 1992).

Formulation of indicator taxa, ecological guilds (groups of ecologically similar species), and habitat-suitability models is often undertaken on riparian (Stauffer and Best 1986; Triquet et al. 1990; Koford 1993) and other terrestrial vertebrates (Yeager 1961; Capen 1981; Verner et al. 1986; Van Horne and Wiens 1991), to assess human impacts (Simberloff and Dayan 1991); certain taxa and guilds are indicative of deforestation impacts and habitat-suitability models can be used to predict the effects of habitat changes on given taxa or guilds. In British Columbia (BC),

ornithologists and other wildlife biologists have focused on logging impacts on riparian and other forests (Orians 1992), including examination of behavioral (nesting or foraging) guilds, abundance of brood parasites (brown-headed cowbird = *Molothrus ater*), species diversity and richness, and total bird abundance (Wetmore et al. 1985; Morgan and Wetmore 1986; Wetmore and Booth 1986; Morgan et al. 1989; Bryant et al. 1993). Habitat use and foraging behavior have also been examined in BC, to establish the importance of floral cover and human impacts on birds in woody and grassy habitats (McIntosh 1986; Hooper and Savard 1991; Morgan et al. 1991; Butler 1992; Moul and Elliott 1994).

The present study is a rapid bioassessment of the potential impact of deforestation on riparian-vertebrate assemblages in two BC river valleys, with focus on birds and spotted frogs (*Rana pretiosa*). Multivariate-statistical analyses and species-diversity indices are used to quantify differences in species and habitat-use guild composition among study reaches, the approach being a pluralistic combination of ecological description and hypothesis testing to better define ecological indicators of deforestation. Treed and deforested reaches are expected to differ in avian-assemblage structure, with higher species diversity in forested reaches due to predicted increases in cavity-nesting and possibly riparian-dependent species and reductions in agricultural-urban taxa.

2.0 Materials and Methods

2.1 Study Watersheds

The two stream valleys studied, the Salmon (SR) and Nicola (NR) river mainstems, are in the Thompson River drainage in the southern-interior (Kamloops) region of BC (Figures 1 and 2) and are of special research and management interest to Environment Canada (Vadas 1997a). Valley vegetation in this region is 'dry forest', dominated by ponderosa pine (*Pinus ponderosa*) in upland habitats, cottonwoods (*Populus* spp.) in riparian habitats, sagebrush (*Artemisia* spp.) in the NR valley, and bunchgrass (erect-stemmed, perennial Poaceae) (Cowan and Guiget 1965; Orchard 1984; Anon. 1993, 1994), a floral mosaic that promotes wildlife biodiversity (Meidinger and Pojar 1991). Deforestation of riparian habitats and bank erosion are extensive here due to agricultural and other impacts, including replacement of bunchgrass by sagebrush because of cattle grazing

(Redpath 1990; Anon. 1993). The valleys support diverse wildlife assemblages and hunting for big game and geese; waterfowl are especially abundant near Nicola Lake (middle NR) and Shuswap Lake (lower SR) (Clark and Brady 1981; MOE 1983; MOEP 1987; Hayes et al. 1993). These watersheds and other riparian forests in southern BC harbor amphibians, reptiles, and other threatened/endangered vertebrates and plants that are rare elsewhere in the province (Clifford 1973; Gregory and Campbell 1984; Orchard 1984; Anon. 1994). Habitat is being restored for riparian and aquatic wildlife in both watersheds, particularly near the lakes (FRAP 1994, 1995).

All study reaches were in the middle and lower river zones between 350 and 600 m elevation, the streams being moderate in size and gradient. SR slopes were 4.0 m/km for both stream zones, whereas slopes for NR were respectively 3.2 and 6.4 m/km in the middle and lower (canyon) zones. Shuswap Lake was downstream from the SR study reaches, whereas Nicola Lake was upstream from the NR study reaches.

2.2 Field Methods

Sampling was conducted during the fall of 1994 for SR (August 28 to September 12) and NR (September 24 to October 8). In both rivers, three reaches (A, B, and C) of differing riparian intactness (see below) were studied at two sites: middle (#1) and lower (#2) mainstems (Figures 1 and 2). Each reach was about 300 to 400 m in stream length (Appendix 3), and three vegetation types were categorized in each river valley (Figures 1 and 2). *Forested* (FO) reaches (SR only) and *semi-forested* (SF) reaches had intact buffer strips (width ≥ 50 m) on both vs. one side(s) of the river, respectively. *Shrubby* (SH) reaches (NR only) had sagebrush-dominated buffer strips on both sides of the river, whereas *grassy* (GR) reaches were dominated by short and/or tall herbs. Growth-form diversity in the lower riparian zone (when cover was classified into three vegetation and two bare-substratum categories), was higher at treed (forested and semi-forested) sites than at unforested (shrubby and grassy) sites (Vadas 1997b).

The junior author (JBN) identified birds during (1) morning (near 800 h) and (2) (usually) afternoon surveys (near 1600 h) and (3) incidental counts, via sight (binoculars) and sound. The former two counts were based on a hybrid (strip-transect and point-count) methodology (cf. Verner 1985; Gebauer 1995). Transect counts were spoken into a tape recorder while JBN

slowly walked along the stream edge for 300 m, with flagged stop points every 50 m to allow 3- to 4-minute point counts (depending on the availability of birds). Surveys took 20 to 30 minutes, and included birds in the water and within 50 m of the stream. Attempts were made not to double count birds that flew ahead of the observer. Although we attempted to count birds only during sunny, calm conditions with moderate temperatures (15-20°C) (cf. DesGranges 1980; Verner 1985), valley weather was variable (Appendix 1) and counts were often low. Moreover, "replicate" counts often yielded different suites of bird species. Hence, the maximum count for the two to three surveys (rather than summed or average counts) was used for each bird species.

Although birds were the main focus of the work, amphibians, reptiles, and mammals were counted during 20-minute, cursory surveys of depositional bars, side channels, and backwater ponds throughout the reaches. Whereas most mammals were identified based on their tracks or feces, most herptiles were spotted or captured by dipnet in vegetation within 1 m of water. Most counts were made during a single morning survey (near 830 h), although incidental counts during aquatic research (Vadas 1997a) were added if the sightings occurred in new locations. Although most taxa were tabulated as presence or absence (Appendix 2), spotted frogs were abundant enough to allow calculation of density (#/1000 m stream length) at each site.

2.3 Data Analysis

Although most non-avian taxa were not analyzed further, densities of spotted frogs were compared across sites to examine zonal and floral habitat-use trends.

The main study focus was on birds. Because the 300-m reaches were not long enough to obtain high avifaunal counts (Appendix 3), we pooled study reaches for analysis. Percent-abundance rather than density data were used to assess assemblage patterns (cf. Emlen 1981). We used multivariate-statistical analyses and the Simpson-Levins diversity index (cf. Vadas 1992, 1994), taxa richness at the species and order levels (cf. McAllister 1994), and habitat-use guilds (see Table 1) to examine vertebrate-assemblage and biodiversity patterns among spatial samples for the two river valleys. The multivariate analyses (see below) was undertaken with PROC FACTOR (SAS 1985), i.e., principal-components analysis (PCA) and two different orthogonal rotations (varimax- [V-FA] and quartimax-factor analyses [Q-FA]) to allow comparisons of techniques.

Two different habitat-use guild classification systems of differing complexity were formulated, to assess their correspondence with our own empirical cover-use classifications and to help establish avian-assemblage differences among sites. Three avifaunal habitat-use guilds ('cover system I') were formulated from Yeager (1961), i.e., FO, SF, and GR. Taxa in these guilds showed primary, secondary (or generalized), and rare (or no) use of woody cover, respectively. Because Yeager's (1961) analysis was based on species richness across cover types for vertebrate taxa (usually families or subfamilies), we assigned all species within these taxa to the same guild. Hence, this guild system is a crude one.

More detailed guild classifications ('cover system II') were formulated from literature data for western North America (Flack 1976; Erksine 1977; Brown 1985; Harcombe 1988; Meidinger and Pojar 1991; Paulson 1992). Most of these authors qualitatively summarized habitat-use distributions across floristic categories, including FO (old-growth or mature, closed-canopy forests), SF (open-canopy parklands, woodlands, or young forests), SF/SH (forest-edge habitats), SH (shrub- or sagebrush-steppe, scrub, seedling, or krummolz vegetation), SH/GR (open habitats), or GR (grasslands, herbaceous meadows, non-woody wetlands, or areas disturbed by clearcuts, avalanches, or fire). In contrast, Flack (1976) provided guild classifications based on nesting habitat, floristic categories including FO/SF (canopy or hole nesters), SH (shrub nesters), or GR (ground nesters). A point index was developed for different floral categories, in which the average-point value for each site could be compared; higher values are indicative of relatively greater abundances of forest-canopy taxa. The floral guilds are FO (7 points), treed (FO-SF, 6 points), woody (FO-SF-SH, 5 points), generalized (4 points), open-canopied (SF-SH-GR, 3 points), unforested (SH-GR, 2 points), and GR (1 point).

These additional publications were also used to define other guild types, including cavity nesters (Scott et al. 1977), riparian species common in the Thompson River (Thomson 1986) or other PNW lotic watersheds (Brinson et al. 1981; Fox 1988), and agricultural-urban indicators; the latter included species that were residents or otherwise relatively prevalent in human-modified habitats. Although only spotted frogs were examined in detail besides birds, guild-II classifications were formulated from the above western references and guild-I classifications from Stebbins (1985) for herptiles and Yeager (1961) for mammals (Appendix 2).

Four sets of multivariate analyses were conducted to examine zonal (site) and floral-use patterns at the species and guild levels. For the zonal analyses, there were four variables to be compared (middle and lower zones for each river), the species and cover-II analyses showing 63 and eight observations (sample sizes), respectively. For the floral-use analyses, there were six variables, i.e., forested habitats on SR, shrubby habitats on NR, and semi-forested and grassy habitats on both rivers. No multivariate analyses were needed for the guild-I data sets, given that the number of observations was small ($N = 3$) and interpretation was thus easy.

Each set of analyses included V-FA, Q-FA, and two interpretations of PCA, to allow comparison of multivariate methods. All three analyses were subjected to 'high-loading' interpretation (PCA = H-PCA), in that all factor axes (or principal components) were retained with highest or moderately high loadings (within 0.10 Pearson units of the highest loading) for at least one variable. PCA was also subjected to unity-eigenvalue interpretation (U-PCA), in that all factor axes were retained with variances (eigenvalues) ≥ 1.0 . In practice, $V-FA > Q-FA > H-PCA > U-PCA$ in the number of retained factors, i.e., V-FA was the most conservative technique because it did not lump (cluster) sites together unless both dominant and subdominant bird species were similar across sites (pers. obs.). For this reason, we focus on V-FA in the results section.

The complexity of species-level results required formulation of multivariate-similarity tables (similar to cluster phenograms) to show the important V-FA axes (vertebrate assemblages) and their component species (cf. Vadas 1992, 1994). Namely, variables showing highest loadings (of the same positive sign) on the same factor axis were considered highly similar, and were stacked vertically in the table. Variables showing only moderately high loadings on the same axis as highly loaded variables were considered moderately similar, the variables being placed horizontally with a similarity bar connecting them. Other variables, which loaded on different axes because they were independent, were not connected by similarity bars.

We focus more on species-diversity than taxonomic-richness results because species richness is very sensitive to N (sample size of individuals) (Preston 1979; McArdle 1990), as suggested by our own data. Samples with lower richness usually had lower N (Table 1), the Spearman (but not Pearson) correlation (Remington and Schork 1985) between bird-species richness and N being

significant ($r_s = 0.66$, $p < 0.05$, $df = 8$) and the correlation between bird-order richness and N being highly significant for Spearman ($r_s = 0.90$, $p < 0.001$) and Pearson analyses ($r = 0.84$, $p = 0.01$). In contrast, species diversity was uncorrelated with N ($p > 0.05$), the correlations actually being somewhat negative.

3.0 Results

3.1 Avifaunal-Assemblage Analyses Across Longitudinal and River Zones

Based on species data (Appendix 1) and V-FA, the middle and lower SR valleys were similar in avifaunal-assemblage structure, in contrast to the fauna of the middle and lower NR (Table 1a). The results reflect the dominance of robins in SR and crows in the middle NR, whereas chickadees, mergansers, and magpies were dominant in the lower NR. Notably, passerines (songbirds) dominated the riparian fauna, although waterfowl were also relatively abundant in the NR valley.

Trends in avian diversity were also apparent (Table 2). Species diversity was somewhat higher in the Nicola than Salmon valley, being higher upstream in SR and downstream in NR, i.e., farther away from riverine lakes. Species richness was generally higher at SR than NR sites, and farther upstream in both rivers. A similar, but less pronounced trend was seen for bird-order richness, and the two rivers yielded 37 vs. 32 bird species, respectively.

Trends in guild composition were also apparent (Tables 2 and 3a). The cover-I analysis showed that 'forested' taxa were dominant at all sites, although 'grassy' taxa were strongly subdominant in the middle NR. Guild diversity was higher upstream in both rivers. The cover-II analysis showed that the two SR sites were similar in guild structure unlike the two NR sites (Table 3a). These results and point averages (Table 2) suggest that the lower NR had a greater abundance of forest-canopy taxa than did the other sites, although the 'generalist' guild was ubiquitous. The results reflect the greater abundance of cavity nesters in NR (especially downstream) and the lesser abundance of agricultural-urban taxa in NR (especially low downstream). The guild-II analysis

yielded no consistent longitudinal trend in biodiversity for the two rivers, whereas the PNW riparian guild dominated all sites and also lacked a consistent longitudinal trend.

3.2 Avifaunal-Assemblage Analyses Across Vegetation Types

Based on the species data (Appendix 1) and V-FA, riparian zones of differing vegetation type often diverged in vertebrate-assemblage structure (Table 1b). There was no strong similarity for the same floral type across rivers, the only similar avifaunal assemblages being those at forested and grassy sites of SR (strong similarity) and unforested sites of NR (partial similarity). The results reflect the differing suites of dominant, subdominant, and/or common species among habitat types. Although crows were dominant in SR's semi-forested and NR's unforested habitats, these three habitats shared only some of the same subdominant species. NR's semi-forested site contained a unique suite of codominant species, namely chickadees, waxwings, and mergansers. Notably, songbirds dominated all floral types, although waterfowl were also important in all NR samples.

Trends in biodiversity were also apparent (Table 2). Species diversity appeared to increase with deforestation in both valleys; grassy habitats in both rivers and SR's semi-forested zones were most diverse and SR's forested habitat was lowest. In contrast, species richness was generally lower in semi-forested habitats for both rivers. A similar, but less pronounced trend was seen for the ordinal richness of birds.

3.3 Vegetation-Guild Analysis for Birds

The results indicate that cavity nesters were relatively more abundant at semi-forested sites in both valleys, whereas the PNW riparian guild dominated all sites (regardless of riparian intactness) and agricultural-urban taxa were most abundant at unforested sites in both rivers (Table 2).

Based on cover-I guild data, 'forested' taxa were dominant at all sites, although 'grassy' taxa were subdominant at the NR sites (Table 2). Guild diversity was somewhat lower in more-forested habitats of both valleys. Although these guild results suggest that forest species dominate the riparian zones of the SR and NR valleys, our habitat-use data suggest that floral generalists were

dominant. Namely, only one bird species was most abundant (relatively) in forested habitats, two were most prominent in semi-forested zones, seven were generalists (abundant in habitats with and without trees), and one was most abundant in grassy habitats (Table 1b), in addition to the use of treed habitats by one frog species. These habitat-use patterns were often divergent from the cover-I guild designations of Appendices 1-2.

Based on cover-II guild data (Table 2) and V-FA, there was some evidence of clustering by riparian intactness, i.e., for treed vs. unforested sites (Table 3b). These results and point averages (Table 2) show some correspondence between avian-guild and riparian-floral compositions, because the 'generalist' guild was ubiquitous and forest-canopy taxa had somewhat higher abundances at woody sites on both rivers. Guild diversity was lowest at forested and shrubby sites.

3.4 Spotted Frog Analysis

Spotted frogs were found only in SR, where the species was more abundant downstream and at treed sites (Table 2). Further spatiotemporal data collection would be necessary to robustly classify this species' habitat use.

4.0 Discussion

4.1 Zonal (Longitudinal and River) Patterns

The species- and guild-level results collectively suggest that the SR and NR valleys differ in avifaunal-assemblage structure, and that NR showed less longitudinal similarity in its riparian fauna. These faunal patterns probably reflect the prevailing environmental conditions; the Nicola-Thompson area was drier than the Shuswap Lake area (CC 1990), stream gradient increased downstream in NR, and NR was sampled under colder conditions than SR (Appendix 3). These environmental differences likely account for the restriction of dippers to the lower NR, since this species prefers steep, swift, rocky streams (Bent 1964; King et al. 1973; Price and Bock 1983), and the apparent lack of spotted frogs in the Nicola valley. The omnipresence of spotted frogs in

SR contrasts with the species' decline farther south in BC's Okanagan region (S.A. Orchard, Royal British Columbia Museum, pers. comm., 1994).

Avifaunal-species richness (SR = 37 and NR = 32) appear relatively high for riparian birds in the eastern and western U.S. (Brinson et al. 1981), probably reflecting the importance of migratory species in the autumn along inland BC streams (Gebauer 1995; Wiebe and Martin 1997). Riverine biodiversity of birds may have been enhanced by the nearby lakes in SR and NR, although diversity was not higher near riverine lakes in our samples (i.e., in the lower SR and middle NR valleys). Because avifaunal diversity was not higher farther downstream (longitudinally), we clearly did not sample far enough upstream to encounter inadequate water conditions and floodplain vegetation for riparian wildlife (Raedeke 1988; Morgan and Lashmar 1993).

4.2 Vegetation-Guild Patterns

Four avifaunal cover guilds emerged from the SR-NR data set, i.e., forested, semi-forested, generalized, and grassy. These categories are similar to Triquet et al.'s (1990) 'mature-forest', 'buffer-strip', 'habitat-generalist', and 'clearcut' guilds, respectively. Our forested and grassy guilds are also similar to Darveau et al.'s (1995) 'forest-dwelling' and 'open-habitat' guilds, respectively, whereas their 'ubiquitous' guild was an amalgam of our semi-forested ('forest-edge') and generalized guilds. Flack (1976) found two of our guilds in aspen (*Populus tremuloides*) forests of western North America; canopy- and cavity-nesting species were most abundant in semi-forested habitats because of their affinity for trees, whereas ground nesters were similar in habitat use to our grassy guild by being associated with herbaceous cover.

Our guild designations for species showed only moderate correspondence with those of cover systems I and II (Table 2 and Appendix 1) and empirical data for BC. First, our treed species were mostly considered 'forested' or 'semi-forested' for system I and 'treed', 'wooded', or 'generalized' for system II. The cedar waxwing is prominent in treed habitats of golf courses in BC (Moul and Elliott 1994), treed habitat use that is consistent with our 'semi-forested' designation. The yellow-rumped warbler showed generalized behavior in Morgan et al.'s (1989) BC data set, being abundant in riparian clearcuts and forests of various ages, contrasting with our

'forested' designation. Second, our generalized and grassy species were often considered 'forested' for system I and 'generalized' or 'open-canopied' for system II. Several BC studies support our designation of the American robin as a generalist, since it is abundant in riparian clearcuts and older forests (Morgan et al. 1989; Bryant et al. 1993) and in habitats with and without woody vegetation on golf courses (Moul and Elliott 1994). Cover-I discrepancies may reflect inaccuracy in guild systems (e.g., Yeager 1961) that employ higher taxa rather than individual bird species (Simberloff and Dayan 1991), whereas cover-II inaccuracy may reflect the limited information that can be drawn from qualitative observations (e.g., Meidinger and Pojar 1991).

The discrepancies in cover-guild designation probably also reflect the limited spatiotemporal extent and sample sizes for the present study. We could not easily sample longer stream reaches as was done by other BC researchers (Gebauer 1995; Wiebe and Martin 1997), because of floral heterogeneity in riparian zones; treed reaches were rarely longer than 300 m because agricultural activities were predominant. Nevertheless, future work should include sampling under streambank rocks for salamanders (Carey 1989; Parker 1993), farther back into the riparian zone (Szaro and Jakle 1985; Gates and Giffen 1991; McGarigal and McComb 1992; Murray and Stauffer 1995), in other seasons (especially spring) (Rice et al. 1980 1983; Butler and Savard 1985; Carter 1991), and with more-detailed (mapping) methods for birds (Erskine 1977), as well as for longer periods of observation (including nocturnal work) and with various types of traps (for ground vertebrates) (Szaro and Rinne 1988; Carey 1989; Bishop and Petit 1992; Mitchell et al. 1993). For example, the greater abundance of spotted frogs than western toads in our lower-riparian samples may have been a result of the spotted frog's greater affinity for water (Orchard 1984); amphibians farther from the stream were harder to find and auditory identification of species was not attempted.

4.3 Avifaunal-Assemblage Patterns Across Vegetation Types

The species-level analysis of assemblages yielded less associations among sites than did the two guild analyses, corroborating the commonly observed divergence of wildlife patterns at different scales of observation (Wiens 1981; Romesburg 1989; Van Horne and Wiens 1991; Savard et al. 1994).

The SR-NR results suggest that semi-vegetated conditions are conducive to wildlife diversity for three reasons. First, semi- and unforested habitats had higher species diversities than did forested sites. Second, semi-forested sites had the highest percent abundances of cavity-nesting birds; these species are sensitive to deforestation and channel alterations (Barclay 1980) because they are often residents (at least south of the frost line) (A.J. Erskine, Canadian Wildlife Service, pers. comm., 1996) and nest and feed in snags of semi-forested and old-growth habitats (Yeager 1955; Flack 1976; Scott et al. 1977; Schroeder 1983; Carey 1989; Orians 1992). Third, brown-headed cowbirds were absent in the fall SR-NR samples (Appendix 1), even though this brood parasite is present in the Thompson River system (MOE 1983; Thomson 1986; Morgan et al. 1989, 1991), is well-known for invading deforested habitats (Flack 1976; Brittingham and Temple 1983; Triquet et al. 1990), and has caused declines of some bird species in the northwestern U.S. (Paulson 1992). Although more extensive avifaunal sampling is required, our results may reflect the fact that grasslands and semi-forested habitats were historically most abundant in BC's southern interior because of natural fire disturbances (BCE 1991; Anon. 1995), such that the native-riparian biota is adapted to these floral conditions. Indeed, fire suppression farther north has reduced floral diversity with negative long-term impacts on boreal wildlife (Kelsall et al. 1977).

Other avian studies in BC indicate that species diversity, richness, and/or total density are enhanced by taller vegetation and surface water in grassy habitats (Butler 1992; Hooper and Savard 1991; Moul and Elliott 1994), coastal forests (Wetmore et al. 1985; Wetmore and Booth 1986; Bryant et al. 1993), and inland-riparian forests in the Nicola (Morgan and Wetmore 1986; Morgan et al. 1989, 1991) and other river systems (Gebauer 1995). Flack (1976) found that open-forest habitats (near 80 trees/ha) were optimal nesting habitats for various bird species in aspen forests of western North America (including BC), particularly at lower elevations. Collectively, these studies suggest that deciduous forests and shrubby habitat are more diverse in bird species and behavioral guilds because of dominance by taxa from both forested and grassy habitats.

Interestingly, the SR-NR bird assemblages were more similar to avifaunas of grassy habitats (golf courses and farmland hedgerows) in south-coastal BC (Butler 1992; Moul and Elliott 1994) than to avian assemblages from coniferous forests along southern tributaries of NR (Morgan et al. 1989, 1991). Of the eight dominant-subdominant bird species from the Butler-Moul data sets,

three were abundant (American robin, black-capped chickadee, and mallard, as well as a different crow species) and three were present (song and white-crowned sparrows and common yellowthroat) in our study sites. In contrast, the Morgan data set yielded several abundant passerines that were rare (*Empidonax* flycatchers, Clarks nutcracker, red-breasted nuthatch, solitary vireo, pine siskin, and dark-eyed junco) or absent (tanagers, cowbirds, and different species of chickadee, finch, and sparrow) in our study sites; only one dominant (yellow-rumped warbler) and subdominant songbird (American robin) were also important in our valley sites. We encountered only one wildlife species characteristic of old-growth, coniferous forests in PNW, namely the bald eagle (Meslow et al. 1981; Meidinger and Pojar 1991), which was rare and seen only in the lower NR valley (Appendix 1). These results support findings that bird species either prefer deciduous or coniferous vegetation in North American forests (Erksine 1977; DesGranges 1980; McGarigal and McComb 1992; Murray and Stauffer 1995), although avifaunal sampling in other seasons would be needed to verify the robustness of our results. The results also highlight the importance of documenting the tree species characterizing riparian zones; because we did not standardize our sites by tree species, some of the avifaunal variation among sites may reflect the differing abundance of alders (*Alnus* spp.), cottonwoods, and ponderosa pine.

4.4 Riparian-Management Considerations

Efforts to protect PNW's riparian vegetation have been directed towards water-quality and fisheries management, with much less focus on habitat needs for riparian vertebrates (Vadas 1997a). Buffer-strip widths to protect stream ecosystems are typically 5 to 30 m in the U.S. (Brinson et al. 1981; Hobbs and Halbach 1981; Hornbeck and Martin 1986; Salo and Cundy 1987) and Canada (van Groenewoud 1977; McAllister et al. 1985; OMNR 1991; Singleton et al. 1994; Scruton et al. 1995). Research to date, however, suggests that buffer strips should be 20 to 100 m wide to maintain population viability and species diversity for riparian trees and resident vertebrates (Bunnell et al., n.d.; Dickson 1989; Keller et al. 1993; Friesen 1994; Singleton et al. 1994; Darveau et al. 1995). Neotropical-migrant birds (passerines and raptors) and large mammals may require even larger buffer strips (up to 200 m) to support home territories or colonies (Gosselink et al. 1990; Triquet et al. 1990; Butler 1991; Keller et al. 1993; Singleton et al. 1994). Wilderness preservation may require even larger widths, i.e., 300 to 500 m (Brinson et

al. 1981; Singleton et al. 1994). Because many bird species "prefer" upland or riparian habitats when these zones differ in relative abundance of floral growth forms (e.g., deciduous vs. coniferous canopies) in the eastern U.S. (Gates and Giffen 1991; Murray and Stauffer 1995) and western North America (Szaro and Jakle 1985; McGarigal and McComb 1992; Wiebe and Martin 1997), and because many species migrate between these zones in different seasons (Szaro and Jakle 1985; Wiebe and Martin 1997), PNW researchers have advocated protection of both zones (buffer \geq 250 m) (McGarigal and McComb 1992; Wiebe and Martin 1997). Evidence from western North America suggests that protection of riparian and upland habitats will benefit migratory vs. resident bird species, respectively (Szaro and Jakle 1985; Orians 1992; Wiebe and Martin 1997).

These results suggest that selective cutting, including tree thinning and varying the width of riparian-buffer strips, will promote floral and wildlife diversity in watersheds of eastern North America (Triquet et al. 1990; Wigley and Roberts 1994; Darveau et al. 1995) and PNW (Szaro and Belfit 1987; Raedeke 1988; Morgan et al. 1989; Orians 1992; Morgan and Lashmar 1993). Protection of tall conifers and deciduous trees, snags, and shrubby undergrowth in forests (Flack 1976; Telfer 1978; Girt 1990; Enns 1994; Moul and Elliott 1994) and native, tall herbs in grasslands (Adams and Gentle 1978; Girt 1990; Hooper and Savard 1991; Anon. 1993) are all necessary to protect riparian and upland wildlife diversity in western Canada (Green and Salter 1987; BCE 1991; Anon. 1995). Savard et al. (1994) found that several waterfowl species were most abundant in semi-forested ponds in the central interior of BC, i.e. 5 to 22% forested. As noted by BC researchers (BCE 1991; Hooper and Savard 1991; Anon. 1995), afforestation in the central and southern interiors (e.g., from fire control) has caused decline of native vegetation and possibly native wildlife.

Cottonwoods, which are often the dominant tree species along PNW streams (Brinson et al. 1981, Morgan and Lashmar 1993), merit buffer-strip protection because they are on the decline in the SR and NR valleys from agricultural and beaver activities (pers. obs., 1994-1995). Cottonwoods and other *Populus* species provide vital cover for various riparian animals in western North America, including arthropods, salamanders, bats, small and large mammals, and birds (Bottorff 1974; Graf 1980; Harcombe 1988; Koford 1993; Morgan and Lashmar 1993).

To synthesize, protection of riparian biodiversity in the Thompson River (TR) drainage will require larger-scale perspectives (cf. McGarigal and McComb 1992). A watershed approach is required because riparian-bird assemblages change longitudinally with elevation and thus floristic changes (Knopf and Samson 1994), which includes downstream decreases in conifers and increases in deciduous trees in the Thompson River drainage (Cowan and Guiget 1965). A landscape-ecology perspective is sorely needed (Schroeder 1987) because riparian corridors enhance avian migrations (Knopf and Samson 1994) and management in southern BC is inadequate; few of the watersheds are undeveloped and protected as parks (Anon. 1980; Thomson 1986; M'Gonigle and Wickwire 1988; MOF 1992). An ecosystem focus allows a more holistic assessment of deforestation and other human impacts; e.g., our own SR-NR study of riparian and aquatic habitat, invertebrates, and vertebrates more robustly suggests that semi-forested habitats are conducive to ecological integrity (Michel 1997; Vadas 1997a).

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TABLES

Table 1(a). Multivariate-similarity tables to assess similarity of riparian-vertebrate assemblages across (a) zonal and (b) floral gradients in the Salmon (SAL) and Nicola (NIC) river valleys, based on varimax-factor analyses for individual species. Data were stratified by site (M = middle and L = lower) or reach (FO = forested, SF = semi-forested, SH = shrubby, and GR = grassy). Sample sites stacked vertically in the diagram loaded highly on the same factor axis, whereas those stacked horizontally with a bar between them were partially similar. DM = dominant, S = subdominant (> 10% abundance), c = common (> 5% abundance), and . = rare or absent species. Guild designations in (b) are based on the Salmon- Nicola analysis for species with sample sizes > 12 individuals (cf. Vadas 1992); GEN = generalized. See Appendix 1 for the data.

Species	SAL-M SAL-L	NIC-M	NIC-L
American robin	DM	-	-
Yellow-rumped warbler	S	-	-
Barn swallow & common yellowthroat	C	-	-
American crow	S	DM	C
Cedar waxwing, American goldfinch, Brewer's blackbird, & cinnamon teal	-	C	-
Common merganser	-	S	S
Black-capped chickadee	-	C	DM
Black-billed magpie	-	-	S
Solitary vireo, white-crowned sparrow, American dipper, & Clarks nutcracker	-	-	C

Table 1 (b).

Species	SAL-GR SAL-FO	SAL-SF	NIC-SF	NIC-SH	NIC-GR	GUILD
Yellow-rumped warbler	S	S	-	-	-	FO
Northern flicker	-	S	-	-	-	-
Black-capped chickadee	-	C	DM	-	S	SF
Cedar waxwing	-	S	DM	-	-	SF
Cinnamon teal	-	-	S	-	-	-
American robin	DM	-	-	-	-	GEN
Barn swallow	C	-	-	-	-	GEN
Belted kingfisher	-	-	-	-	-	GEN
American crow	C	C	S	DM	DM	GEN
Brewer's blackbird	-	DM	-	-	S	GEN
Common merganser	-	S	DM	S	S	GEN
Black-billed magpie	-	-	C	C	C	GEN
American goldfinch	-	-	-	C	C	-
Common yellowthroat	C	-	-	-	-	GR
Killdeer	-	-	-	-	C	-

Table 2. Percent abundance of avian habitat-use guilds, avian biodiversity, and frog abundance in the two river valleys. Div = Simpson-Levins diversity across species or guilds, agric. = agricultural, richn. = taxonomic richness, PNW = Pacific Northwest, and frog density = # of spotted frogs/1000 m stream length. See the text for floral-II point designations; higher values indicate greater abundances of more-forested guilds. See Appendices 1-3 for input data and Table 1 for abbreviations.

Guild	Salmon R.		Nicola R.		Salmon River			Nicola River		
	M	L	M	L	GR	FO	SF	SH	SF	GR
<i>Floral-I avifaunal guilds</i>										
Forested	68	81	51	64	62	87	60	52	62	49
Semi-forested	9	6	10	8	12	2	21	9	4	16
Grassy	23	13	39	27	26	12	19	39	35	35
Guild Div.	1.9	1.5	2.4	2.0	2.1	1.3	2.3	2.3	2.0	2.6
<i>Floral-II avifaunal guilds</i>										
Forested	1	0	17	10	1	0	0	18	17	12
Treed	7	4	4	24	7	3	7	7	8	12
Woody	20	28	8	24	5	36	24	4	21	10
Generalized	45	50	49	31	38	52	55	61	37	39
Open-canopied	17	8	9	12	29	2	12	7	5	17
Unforested	6	6	5	0	8	6	0	0	0	10
Grassy	5	4	8	0	11	2	2	4	13	1
Average points	4.0	4.0	4.2	4.9	3.4	4.3	4.2	4.6	4.5	4.3
Guild Div	3.6	2.9	3.4	4.2	3.9	2.5	2.7	2.4	4.3	4.4
<i>Other avifaunal guilds</i>										
PNW riparian	99	99	100	96	100	99	98	96	100	99
Cavity-nesting	9	9	26	44	5	8	21	23	41	27
Agric.-urban	66	60	53	22	68	61	52	57	19	60
<i>Other avifaunal parameters</i>										
Species richn.	31	20	22	17	25	21	13	18	13	17
Ordinal richn.	8	8	8	6	8	8	6	6	6	7
Species Div.	10	5	7	9	8	4	8	6	7	8
Total #	121	195	158	59	95	139	42	56	78	83
<i>Spotted frog abundance</i>										
Density	6.1	14.5	0	0	6.0	11.0	14.5	0	0	0

Table 3. Multivariate-similarity tables to assess similarity of riparian-vertebrate assemblages across (a) zonal and (b) floral gradients in the two river valleys, based on varimax-factor analyses for eight guilds (i.e., cover-II analysis). See Tables 1 and 2 for the data and format; only dominant and subdominant guilds are indicated.

Guild	(a)			(b)				
	SAL-M SAL-L	NIC-M	NIC-L	SAL-FO SAL-SF	NIC-SF	NIC-SH	NIC-GR	SAL-GR
Forested	-	S	S	-	S	S	S	-
Treed	-	-	DM	-	-	-	S	-
Woody	S	-	DM	S	S	-	S	-
Generalized	DM	DM	DM	DM	DM	DM	DM	DM
Open-canopied	S	-	S	-	-	-	S	DM
Unforested	-	-	-	-	-	-	S	-
Grassy		-	-	-	S	-	-	S

FIGURES

Figure 1. Map of the Salmon River watershed. The study sites (#1 and 2) on the river include three reaches (A, B, and C) of differing riparian intactness (as indicated). The Salmon watershed is northeast of the Nicola watershed (figure 2), originating near 50°10' north and 119°45' west coordinates. Asterisks (*) indicate reaches with obvious cattle damage.

Figure 2. Map of the Nicola River watershed. The study sites (#1 and 2) on the river include three reaches (A, B, and C) of differing riparian intactness (as indicated). The Nicola River originates near 50°10' north and 119°45' west coordinates. Asterisks (*) indicate reaches with obvious cattle damage.

APPENDIX

Appendix 1 Percent abundance and habitat-use guilds of riparian-bird species in the Salmon (SAL) and Nicola river (NIC) valleys. Data were stratified by site (M = middle and L = lower) and reach (FO = forested, SF = semi-forested, SH = shrubby, and GR = grassy). Floral guild-I designations match reach abbreviations (FO, SF, or GR). Floral guild-II designations were based on information from western North America, or (rarely) were identical to guild-I assignments if no information was available; the guilds include FO, TR (treed = FO-SF), WO (woody = FO-SF-SH), GN (generalized), OC (open-canopied = SF-SH-GR), SH, UF (unforested = SH-GR), and GR. The symbol * refers to species not common in lotic watersheds in the Pacific Northwest, ^ designates species found in agricultural- urban areas of British Columbia, and # refers to cavity nesters. Species names follow Banks et al. (1987). See the text for literature data used to formulate habitat-use guilds and Table 2 for sample sizes.

Taxa	SAL		NIC		SAL			NIC			Guild	
	M	L	M	L	GR	FO	SF	SH	SF	GR	I	II
Ansiformes												
Mallard (<i>Anas platyrhynchos</i>)	1	4	1	0	6	1	0	4	0	0	GR	GR
Northern shoveler (<i>A. clypeata</i>)	2	0	0	0	2	0	0	0	0	0	GR	GR
Cinnamon teal (<i>A. cyanoptera</i>)	0	0	7	0	0	0	0	0	13	1	GR	GR
Common merganser (<i>Mergus merganser</i>)	1	0	17	10	1	0	0	18	17	12	GR	FO#
Ciconiformes												
Great blue heron (<i>Ardea herodias</i>)	2	1	1	0	1	1	2	0	1	0	SF	GN
Coraciiformes												
Belted kingfisher (<i>Ceryle alcyon</i>)	3	3	1	3	5	1	7	2	3	1	GR	TR
Gruiformes												
Sandhill crane (<i>Grus canadensis</i>)	0	0	2	0	0	0	0	0	0	4	GR	UF^
Sora (<i>Porzana carolina</i>)	1	0	0	0	1	0	0	0	0	0	GR	GR
Charadriiformes												
Sandpiper (<i>Calidris</i> spp. ^a)	2	0	0	0	1	0	2	0	0	0	GR	GR
Killdeer (<i>Charadrius vociferus</i>)	0	1	3	0	0	1	0	0	0	6	GR	UF^

Appendix 1 continued.

Taxa	SAL		NIC		SAL			NIC			Guild	
	M	L	M	L	GR	FO	SF	SH	SF	GR	I	II
Galliformes												
Ring-necked pheasant (<i>Phasianus colchicus</i>)	0	1	0	0	0	1	0	0	0	0	SF	GR^*
Ruffed grouse (<i>Bonasa umbellus</i>)	0	0	0	2	0	0	0	2	0	0	SF	GN
Falconiformes												
Osprey (<i>Pandion haliaetus</i>)	2	0	1	3	1	1	0	0	1	2	SF	TR
American kestrel(<i>Falco sparverius</i>)	2	0	1	0	1	0	5	2	0	0	SF	GN^*
Merlin (<i>F. columbarius</i>)	0	1	0	0	1	0	0	0	0	0	SF	GN#
Cooper's hawk (<i>Accipiter cooperii</i>)	1	0	0	0	0	0	2	0	0	0	SF	GN^*
Red-tailed hawk (<i>Buteo jamaicensis</i>)	0	0	2	0	0	0	0	2	1	1	SF	GN^
Bald eagle (<i>Haliaeetus leucocephalus</i>)	0	0	0	3	0	0	0	4	0	0	SF	TR
Piciformes												
Northern flicker (<i>Colaptes auratus</i>)	2	0	2	2	1	1	7	2	0	0	FO	GN#
Downy woodpecker (<i>Picoides pubescens</i>)	0	1	0	0	1	0	0	0	0	0	FO	TR#
Hairy woodpecker (<i>P. villosus</i>)	0	0	1	3	0	0	0	0	1	4	FO	TR#
Passeriformes												
Tyrannidae												
Western wood-pewee (<i>Contopus sordidulus</i>)	1	0	1	0	0	1	0	2	0	0	FO	WO
Willow flycatcher (<i>Empidonax traillii</i>)	0	1	0	0	1	0	0	0	0	0	FO	OC
Alder flycatcher (<i>E. alhorum</i>)	0	1	0	0	1	0	0	0	0	0	FO	OC^
Hirundinidae												
Northern rough-winged swallow (<i>Stelgidopteryx serripennis</i>)	1	0	0	0	1	0	0	0	0	0	GR	UF
Barn swallow (<i>Hirundo rustica</i>)	5	4	0	0	6	4	0	0	0	0	GR	UF^

Appendix 1 continued.

Taxa	SAL		NIC		SAL			NIC			Guild	
	M	L	M	L	GR	FO	SF	SH	SF	GR	I	II
Corvidae												
Common raven (<i>Corvus corax</i>)	1	0	0	0	0	1	0	0	0	0	FO	GN^
American crow (<i>C. brachyrhynchos</i>)	10	10	28	7	4	9	26	32	13	25	FO	GN^
Black-billed magpie (<i>Pica pica</i>)	2	3	3	12	7	0	0	7	5	5	FO	OC^
Steller's jay (<i>Cyanocitta stelleri</i>)	1	0	0	0	0	1	0	0	0	0	FO	GN
Clarks nutcracker (<i>Nucifraga columbiana</i>)	0	0	0	5	0	0	0	4	0	1	FO	GN*
Paridae												
Black-capped chickadee (<i>Parus atricapillus</i>)	2	6	6	24	0	6	10	0	21	10	FO	WO#
Sittidae												
Red-breasted nuthatch (<i>Sitta canadensis</i>)	1	0	1	3	0	1	0	0	3	1	FO	TR#
Troglodytidae												
House wren (<i>Troglodytes aedon</i>)	1	0	0	0	0	1	0	0	0	0	GR	GN#^
Winter wren (<i>T. Troglodytes</i>)	0	0	0	2	0	0	0	2	0	0	GR	TR#
Cinclidae												
American dipper (<i>Cinclus mexicanus</i>)	0	0	0	7	0	0	0	4	3	0	GR	GN
Muscicapidae												
American robin (<i>Turdus migratorius</i>)	21	36	0	3	27	39	0	4	0	0	FO	GN^
Bombycillidae												
Cedar waxwing (<i>Bombycilla cedrorum</i>)	0	0	9	0	0	0	0	0	19	0	FO	GN
Vireonidae												
Warbling vireo (<i>Vireo gilvus</i>)	0	0	1	0	0	0	0	2	0	0	FO	WO
Solitary vireo (<i>V. Solitarius</i>)	1	0	0	5	0	1	0	0	0	4	FO	TR

Appendix 1 continued.

Taxa	SAL		NIC		SAL			NIC			Guild	
	M	L	M	L	GR	FO	SF	SH	SF	GR	I	II
Fringillidae												
Pine siskin (<i>Carduelis pinus</i>)	4	0	0	0	0	3	0	0	0	0	GR	WO^
American goldfinch (<i>C. tristis</i>)	1	0	6	0	1	0	0	7	0	7	GR	GN^
Emberizidae												
Parulinae												
Yellow warbler (<i>Dendroica petechia</i>)	1	0	0	0	0	0	2	0	0	0	FO	GN^
Yellow-rumped warbler (<i>D. coronata</i>)	12	22	0	0	5	26	14	0	0	0	FO	WO
Common yellowthroat (<i>Geothlypis trichas</i>)	13	1	0	0	14	2	0	0	0	0	FO	OC^
Emberizinae												
Song sparrow (<i>Melospiza melodia</i>)	2	1	1	0	1	1	5	4	0	0	GR	GN^
White-crowned sparrow (<i>Zonotrichia leucophrys</i>)	0	0	0	5	0	0	0	0	0	4	GR	GN
Dark-eyed junco (<i>Junco hyemalis</i>)	0	1	0	0	0	0	5	0	0	0	GR	GN
Icterinae												
Red-winged blackbird (<i>Agelaius phoeniceus</i>)	1	1	0	0	2	0	0	0	0	0	SF	OC
Brewer's blackbird (<i>Euphagus cyanocephalus</i>)	2	4	6	0	5	0	12	0	0	12	SF	OC^

^a Least (*C. minutilla*) and/or western sandpiper (*C. mauri*).

Appendix 2 Numerical data for spotted frogs and presence-absence data (+ indicates presence) for other herptiles and mammals in the two study valleys. Habitat-use guild classifications are also given based on literature data (see the text). See Appendix 1 for format.

Taxa	SAL		NIC		SAL			NIC			Guild	
	M	L	M	L	GR	FO	SF	SH	SF	GR	I	II
AMPHIBIANS												
Western toad (<i>Bufo boreas</i>)	+	+	0	+	+	+	0	0	0	+	SF	GN
Spotted frog (<i>Rana pretiosa</i>)	6	16	0	0	4	8	10	0	0	0	SF	GN
REPTILES												
Garter snake (<i>Thamnophis</i> spp. ^a)	+	+	0	0	0	+	+	0	0	0	SF	GN [^]
MAMMALS												
Northern water shrew (<i>Sorex palustris</i>)	+	0	0	0	+	0	0	0	0	0	FO	WO
Deer (<i>Odocoileus</i> spp. ^b)	+	+	+	+	+	0	+	+	+	+	SF	GN [^]
Black bear (<i>Ursus americanus</i>)	+	+	+	0	+	+	+	0	+	0	SF	GN [^]
Raccoon (<i>Procyon lotor</i>)	+	+	0	0	+	+	0	0	0	0	FO	GN [^]
Coyote (<i>Canis latrans</i>)	0	0	0	+	0	0	0	+	0	+	SF	GN [^]
Yellow-pine chipmunk (<i>Tamias amoenus</i>)	+	0	+	0	+	+	0	0	+	0	FO	WO*
Red squirrel (<i>Tamiasciurus hudsonicus</i>)	+	+	0	+	0	+	0	+	0	0	FO	TR
Muskrat (<i>Ondatra zibethica</i>)	+	+	+	0	+	+	0	0	+	0	GR	GR

^aCommon (*T. sirtalis*) and/or western terrestrial garter snake (*T. elegans*).

^bMule (*O. hemionus*) and/or white-tailed deer (*O. virginianus*).

Appendix 3. Riparian-bird counts, reach (thalweg) lengths, and air temperatures ($^{\circ}\text{C}$) for each study reach. Bird counts were the sums of maximum species values for three surveys (except two counts for Salmon River #1A). The symbol -- represents lack of an afternoon count, whereas m depicts missing temperature data. See Appendix 1 for other abbreviations.

Reach Vegetation Category	Salmon River						Nicola River					
	Site #1			Site #2			Site #1			Site #2		
	A	B	C	A	B	C	A	B	C	A	B	C
	GR	FO	SF	SF	GR	FO	SH	SF	GR	SF	GR	SH
Total number of birds	68	29	24	18	27	150	34	60	64	18	19	22
Reach length (dam)	31	35	33	36	36	38	37	39	38	33	42	28
Morning air temperature	23	8	17	17	10	14	24	13	3.5	5	5	8
Afternoon air temperature	-	21	18	25	m	m	16	18	19	19	9	17