Assessment of Habitat of Wildlife Communities on the Snake River, Jackson, Wyoming

by

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Abstract. The composition of the wildlife community in western riparian habitats is influenced by the horizontal and vertical distribution of vegetation, the physical complexity of the channel, and barriers to movement along the corridor. Based on information from the literature and a workshop, a model was developed to evaluate the wildlife community along the Snake River near Jackson, Wyoming. The model compares conditions of the current or future years with conditions in 1956, before the construction of levees along the river. Conditions in 1956 are assumed to approximate the desirable distribution of plant cover types and the associated wildlife community and are used as a standard of comparison in the model. The model may be applied with remotely sensed data and is compatible with a geographic information systems analysis. In addition to comparing existing or future conditions with conditions in 1956, the model evaluates floodplain and channel complexity and assesses anthropogenic disturbance and its potential effect on the quality of wildlife habitat and movement of wildlife in the riparian corridor.

Key words: Riparian, community, wildlife, habitat, model.

This document provides a method and useful information for assessing changes and mitigating adverse changes of wildlife habitat along 40 km of the Snake River near Jackson, Wyoming. The changes were created by the Jackson Hole–Snake River levee system that was constructed between the early 1950's and the late 1970's.

On 25 and 26 June 1991, a workshop was held to develop an assessment technique for evaluating changes in the wildlife community of the affected reaches of the Snake River near Jackson, Wyoming. The workshop concept was proposed by the tri-agency team (U.S. Fish and Wildlife Service [Service], Wyoming Game and Fish Department, and U.S. Army Corps of Engineers) responsible for evaluating the effects of the levees and was supported by the National Ecology Research Center of the Service. The objective of the workshop was to develop a community-level, quantitative model for evaluating wildlife habitat in the floodplain with primarily remotely sensed data. The desire for a community-level model stems from an interest in moving beyond assessment and management of habitat for single species. As noted by Schroeder (1987), the interest in community-level approaches for wildlife-habitat assessment is growing. To be of most use, assessment of a community should be based on accepted ecological concepts and allow quantification of wildlife community features.

Aerial photography of the study area was available from 1956, before major construction of levees and significant modification of the floodplain. Workshop participants assumed that richness and abundance of wildlife species in 1956 are an acceptable standard of optimum conditions. Workshop participants agreed that the model output should be a value from 0 to 1.0, with 1.0 representing species richness and abundance patterns of riparian-dependent wildlife in 1956. It was further assumed that measurements of the vegetation and physical features of the riparian habitat could be compared with conditions in 1956 and used to predict changes in the wildlife community.

The model is driven mostly by variables whose values can be obtained from maps and aerial photographs. The model does not specifically address the habitat needs of species of special regional or national concern, such as the Snake River cutthroat trout (*Oncorhynchus clarki pleuriticus*), trumpeter swan (*Cygnus buccinator*), and bald eagle (*Haliaeetus leucocephalus*). Assessment of habitat conditions for species of special concern should be addressed separately from a general evaluation of the riparian wildlife community.

Three major criteria are assumed to influence species richness of wildlife in the study area: (1) changes in complexity and area of plant associations, particularly conversion of wetland cover types to more xeric plant communities from alterations in hydrologic patterns in the floodplain; (2) changes in physical complexity of the river channel and floodplain from alterations in the hydrologic regime; and (3) access to and connectivity of plant associations that affect dispersal or migration of wildlife in the floodplain. Each of these criteria is described in detail in the following pages. The first major section presents information from the literature on use of western riparian habitats by wildlife. The goal of the workshop was to use existing information for the model and to develop the model in a short time. Therefore, much of the information is from outside the study area, but the general concepts are assumed to be applicable to the Snake River. The second major section presents the habitat suitability index (HSI) model for estimating the quality of the riparian habitat and the logic behind its development.

The workshop was conducted by the authors. Workshop participants included steering committee members of the Jackson Hole Flood Protection Project and biologists familiar with resource issues in the area, namely, F. Goodsell, Bureau of Reclamation; M. Whitfield, Greater Yellowstone Coalition; L. Glenn, W. Rigsby, and S. van Gykabeek, Trout Unlimited; T. Collins, J. Kiefling, D. Moody, and B. Oakleaf, Wyoming Game and Fish Department; L. Mettler, U.S. Army Corps of Engineers; A. Anderson, V. Moran, and S. Oddan, Service; and J. Kremer, U.S. Soil Conservation Service.

Characteristics of Riparian Wildlife Habitat

Riparian systems are the interface between aquatic and upland ecosystems and are characterized by distinct vegetation and fauna, high productivity, and high densities and diversity of wildlife species (Mitsch and Gosselink 1986). Riparian ecosystems in the intermountain west have a wide variety of plant communities because of elevational, geomorphic, and climatic influences (Brinson et al. 1981; Johnson and Lowe 1985). Attributes that augment the diversity of wildlife species and productivity of riparian communities include predominance of woody plant species, high soil moisture and surface water, diversity and interspersion of physical features of habitat and plant communities, and corridors that facilitate animal dispersal and migration (Brinson et al. 1981).

Because of their unique attributes and relative rarity and the declining diversity of their fauna and flora, riparian communities have been recognized on a regional and national level (Johnson and Carothers 1982; Szaro and Rinne 1988; Flather and Hoekstra 1989). More than 70% of the riparian areas in the United States have been altered (Brinson et al. 1981), and the average annual loss of forested wetlands in the Rocky Mountain states is about 1% (Cooper and Lee 1987). This annual rate of loss is significant because of the scarcity of western riparian ecosystems and the importance of their ecological functions and their effect on local and regional species diversity of wildlife (Warren and Schwalbe 1985). The Fish and Wildlife Coordination Act report for the Snake River Levee Project (U.S. Fish and Wildlife Service 1990) notes the occurrence of 192 vertebrate species in the cottonwood (*Populus* spp.)—riparian and associated wetland habitat types in the vicinity of Jackson, Wyoming.

Cumulative effects of human activities in and adjacent to wetlands have seriously reduced the quality and quantity of wetlands (Brown 1989). Elimination and degradation of riparian ecosystems and corresponding losses of wildlife habitat can be attributed to channel alteration, ground water pumping, surface water diversion, impoundment, direct removal of riparian vegetation, alteration of flooding regimes, and urbanization (Brinson et al. 1981). Contaminants, recreation, grazing, and habitat fragmentation also degrade viable habitat for wildlife in riparian systems.

Factors of Wildlife Diversity in Riparian Habitats

Factors of habitat diversity and the ability of riparian communities to support ecologically diverse and productive wildlife communities include horizontal and vertical diversity of size, shape, and spatial distribution of vegetation types and successional stages; physical complexity of the channel and floodplain; and spatial relations in the riparian plant community and the drainage system. Diminished habitat quality in riparian communities stems from at least two major causes: loss of diversity in biotic or physical composition and isolation or fragmentation.

Structure and Abundance of Riparian Vegetation

Diversity and productivity of plant communities adjacent to riverine channels are largely influenced by natural fluctuations in flow regime, which influence the transport of nutrients and successional composition of vegetation in floodplains (Ohmart et al. 1977; Fredrickson 1979; Brinson et al. 1981). Richness and abundance of wildlife seem to be more dependent on the structure and diversity of plant communities than on the presence of particular associations of plant species (Szaro 1980; Brinson et al. 1981; Raedeke et al. 1988). The cover types in the model (Table 1) are based primarily on differences in vegetation structure and were developed by the tri-agency team. Foliage density, height, and patchiness of vegetation affect habitat complexity and species diversity and richness of wildlife in a riparian community (Brinson et al. 1981). Reductions in plant cover typically eliminate availability and quality of concealment, forage, and the density of prey species for carnivores (Raedeke et al. 1988). Reduced complexity in foliage height or replacement of multi-aged with even-aged stands of vegetation reduces complexity of vertical structure per unit area, resulting in concurrent loss of habitat diversity and diminished wildlife species richness (Brinson et al. 1981).

Horizontal diversity between stands influences interstand complexity and wildlife species richness in riparian communities. Distinct edges between communities and greater numbers of plant strata are associated with greater maturity of the vegetation complex in the riparian zone and greater diversity of habitats (Minshall et al. 1989). Diverse associations of species and age classes provide additional niches and strata per unit area for wildlife. In contrast, large uniform stands of the same age or monotypic species composition support lower richness of wildlife species per unit area.

Use of riparian habitat by birds has received more attention than use of it by other species groups (Brinson et al. 1981). No other habitat associations in North America are believed to be as important as riparian wetlands to noncolonial nesting birds (Carothers and Johnson 1975). Riparian ecosystems are critically important to non-breeding and migrant bird populations as well. Nationwide, more than 250 species of birds use riparian habitats (Szaro 1980; Brinson et al. 1981). Of the 192 vertebrate species in the riparian habitat off the Snake River, 150 (78%) are birds (U.S. Fish and Wildlife Service 1990). Of these 150 species, approximately 75% are passerines (songbirds).

Factors of use of riparian habitats by passerine birds include the quality of adjacent habitats, structural diversity, species composition of vegetation, and location of habitat (Stevens et al. 1977). Plant structure reflects resource distribution, which affects abundance, diversity, and distribu-

Table 1. *Vegetation classification scheme for the Snake River near Jackson, Wyoming. Terminology generally follows Cowardin et al. (1979).*

System	Assigned code	Subsystem	Class	Subclass and dominance type
Riverine	R2AB3	Lower perennial	Aquatic bed	Rooted vascular
	R3AB3	Upper perennial	Aquatic bed	Rooted vascular
	R3US1	Upper perennial	Unconsolidated shore	Cobble–gravel
	R3UB1	Upper perennial	Unconsolidated bottom	Cobble–gravel
Palustrine	PAB3	Palustrine	Aquatic bed	Rooted vascular
	PUB	Palustrine	Unconsolidated bottom	
	PEM1[a]	Palustrine	Emergent	Persistent
	PSS1	Palustrine	Scrub–shrub	Broad-leaved deciduous
	PF01	Palustrine	Forested	Broad-leaved deciduous
Riparian	MG[b]	Riparian	Grassland	
	MS	Riparian	Shrubland	
	MFA	Riparian	Forested	Aspen >30%, <30% other
	MFALP[c]	Riparian	Forested	Aspen or lodgepole pine >30%, <30% other
	MFC[c]	Riparian	Forested	Cottonwood >30%, <30% other
	MFCA[c]	Riparian	Forested	Cottonwood or aspen >30%, <30% other
	MFCS[c]	Riparian	Forested	Cottonwood or spruce >30%, <30% other
	MFLP[c]	Riparian	Forested	Lodgepole pine >30%, <30% other
	MFS[c]	Riparian	Forested	Spruce >30%, <30% other
	MFW[c]	Riparian	Forested	Willow >30%, <30% other
Upland				
	N[b]			

[a] Water regime modifiers for palustrine emergent vegetation classes: C = seasonally flooded (wet meadows), F = semipermanently flooded (cattail, bulrush, etc.), M = permanently flooded (open water).
[b] Modifiers to upland and riparian grassland: r = residential, s = sagebrush. Modifiers to all classes: b = beavers, f = farmed, h = diked, x = excavated.
[c] These vegetation classes must be followed by modifiers for height and coverage: height class 1 = 6.1–12.2 m (20–40 feet), class 2 >12.2 m (>40 feet); coverage class 1 = 30–70%, class 2 >70%.

tion of birds. Stauffer and Best (1980) concluded that vertical stratification of vegetation, sapling or tree size, plant species richness, and the presence of special habitat features (e.g., snags) were the habitat features most frequently related to abundance of bird species in riparian habitat.

Raptors and other predatory species meet many of their needs in riparian communities, which have comparatively high populations of prey and unique habitat features (e.g., roost and nest sites, protective cover; Lee et al. 1987; Lingle 1989). Several raptors, including ospreys (*Pandion haliaeetus*) and bald eagles, depend on riparian habitats for reproduction, wintering, and stopovers during migration (Vahle et al. 1986; Hunter et al. 1987). Landscape and riparian features important to raptors should be considered in conjunction with site-specific characteristics including the quality of surrounding habitat types and the importance of riparian zones as corridors between vegetation types (Lee et al. 1987). Structurally complex systems provide maximum net productivity crucial to raptors and their prey base in the western states.

Community structure and abundance of small mammals seem to be strongly related to habitat diversity (Geier and Best 1980; Moulton et al. 1981; Racey and Euler 1982). Whereas microhabitat (e.g., physical characteristics in an individual home range) structure and heterogeneity affect habitat selection and density of small mammals, macrohabitat (e.g., riparian communities) affects stability and community composition of small mammal populations (Adler 1988). Diversity of small mammal populations is increased through maintenance or enhancement of structurally diverse macrohabitats.

The specific needs of medium to large mammalian species in relation to riparian communities have received comparatively little attention, and knowledge of the value of these communities is largely unquantified (Ohmart and Anderson 1986; Raedeke et al. 1988). Characteristics of riparian systems important to large mammals include abundance and concentration of prey species, productivity and diversity of vegetation, early spring availability of forage, reduced snow accumulations, surface water and associated aquatic habitats, and the linear continuity of these habitats that facilitates movement and migration by animals (Jonkel and Cowan 1971; Pederson et al. 1979; Kellyhouse 1980; Reed 1981; Harris 1984; Raedeke et al. 1988). Minks (*Mustela vison*) attain their greatest densities in riparian habitats that provide numerous potential den sites and abundant foraging cover (Melquist et al. 1981; Birks and Linn 1982). High order streams in lowlands have the greatest habitat value for large mammalian species in the Northwest, but these areas are the most threatened by development (Raedeke et al. 1988).

The value of a riparian ecosystem to large mammals partially depends on its degree of difference from adjacent upland plant communities and increases with increasing differences (Brinson et al. 1981; Raedeke et al. 1988). The most important feature of riparian habitats for larger mammals is production of food, including terrestrial and aquatic vegetation, prey, and carrion (Krausman et al. 1985; Raedeke et al. 1988). Because of high soil moisture, presence of surface water, greater productivity of alluvial soils, and high structural diversity, riparian communities generally produce more food per unit area than uplands.

Losses of riparian wildlife habitat from inundation, urbanization, and conversion to other land uses are obvious. A less conspicuous damage of wildlife habitat quality results from livestock grazing in riparian communities throughout the intermountain west (Cope 1979; Cooper and Lee 1987). No grazing system has been beneficial to wildlife in riparian communities (Behnke 1979). Excessive concentrations of livestock in riparian ecosystems can reduce water quality, degrade channel morphology, inhibit regeneration of woody vegetation, reduce density and quality of herbaceous vegetation, and alter plant composition and structural characteristics (Cope 1979; Hogan 1979; Munther 1982; Kauffman and Krueger 1984; Kochert et al. 1986; Szaro and Rinne 1988). Lotic habitats in livestock exclosures in Colorado had narrower stream widths, greater stream depths, and riparian vegetation of greater density and diversity than grazed stream reaches (Stuber 1985). Although a grazed riparian study site in Nevada did not seem to have received excessive use by livestock, species diversity, species richness, and biomass of small mammals were all higher on a comparable ungrazed site (Medin and Clary 1989). The most obvious differences in vegetation between sites was a reduction of forb and graminoid heights and graminoid biomass by approximately 50% in the grazed site. Larger home range size and lower densities of minks were recorded in Montana where riparian communities supported lower plant density because of livestock grazing (Mitchell 1961). Numbers and species richness of birds were greater in ungrazed exclosures than in grazed stream reaches in Arizona and New Mexico (Szaro and Rinne 1988). Differences in physical and vegetative attributes between grazed and ungrazed riparian sites included greater bank stability and higher abundance of woody vegetation on ungrazed sites.

Channel and Floodplain Complexity

Channel Configuration

Multiple channels from lateral migration of the main channel and sinuosity in lotic systems contribute to habitat diversity of riverine and riparian communities. In riverine systems where large amounts of debris and sediment are dropped rapidly, channels are braided and have a high width-to-depth ratio (Heede 1980; Platts et al. 1983). Physical characteristics of braided river channels include numerous active side channels; relatively flat, shallow beds; heavy sediment load; erodible banks; and frequent and rapid variation in discharge.

The consequences of stream braiding include increased surface area of banks, greater potential for accumulation of sediments and organic materials, and greater deposition of organic material in the aquatic system from adjacent riparian vegetation (McArthur 1989). Biological diversity is greater in habitats of a braided stream than in habitats of a nonbraided stream of comparable size because the horizontal dimension of a braided stream is larger and therefore promotes a more diverse food base (Brinson et al. 1981; McArthur 1989). Erosion and deposition of sediments associated with braided or meandering channels have physical features such as meander bends, point bars, undercut banks, vegetated banks, and diversity in bed material that provide microhabitats for feeding and breeding by numerous aquatic and wetland-dependent wildlife species. In contrast, constructed channels typically reduce stability of stream banks, lower diversity of microhabitats, reduce abundance or completely eliminate vegetation at the interface of land and water, and increase loads of suspended solids.

Diversity of wildlife species in riparian communities is enhanced by the presence of wetland and open-water cover types in addition to the lotic environment (Fredrickson 1978; Brinson et al. 1981; Sedell and Froggatt 1984; Holden et al. 1986). Wetland cover types (e.g., oxbows, seasonally flooded wetlands, spring creeks) in close association with the riverine channel enhance structural and vegetation diversity.

Dynamically Stable Islands

As a consequence of lateral movement of the main channel, side channels are developed that create and maintain islands throughout the floodplain. Diversity in the structure and composition of plant communities on in-channel islands provides diversity in the structure and vegetation of habitats in the floodplain and in the channel. Because islands and their associated plant communities are alternately destroyed and created, they provide a relatively stable area and diversity of habitats. Seasonally high discharges in channelized reaches or levees increase erosion of these islands and decrease habitat diversity in modified reaches of the floodplain. Although sediment deposition in modified reaches may provide suitable substrates for establishment of early seral stages of wetland vegetation, seasonally high discharges prevent long-term persistence of islands.

Overbank Flooding

Natural levees (from seasonal increases in discharge), overbank flooding, and sediment deposition generally support a high diversity of various wetland types and vegetation communities in riverine floodplains. Natural levees tend to regulate the rate at which river water is distributed across the floodplain during flooding (Minshall et al. 1989). Modification of water regimes throughout the floodplain may significantly influence the structure of riparian communities through seasonal reduction in surface water and deposition of organic debris and through alteration in complexity and diversity of wetland habitats. Stabilized or static water regimes, which are either wetter or drier than natural conditions (Fredrickson 1980), eliminate or greatly modify plant and animal associations tied to fluctuating water regimes. Longer flood duration and greater water depth are characteristic of riverine channels in levees. Conversely, elimination of seasonal flooding of riparian communities results in vegetation and faunal shifts away from wetland-associated species (Martin 1977; Ohmart et al. 1977; Mitsch and Gosselink 1986). Reduction or elimination of peak flows throughout the floodplain can eventually lower the water table, which causes replacement of wetland-associated communities with vegetation of more xeric conditions.

Shoreline Complexity

Partial or total removal of streamside vegetation diminishes diversity and quality of riparian habitat and increases sediment loads, which reduces bedform roughness and thereby decreases lotic habitat diversity (Platts et al. 1985). The importance of debris in riverine channels is in its effect on channel hydraulics and ultimately on populations of prey species (Angermeier and Karr 1984; Sedell and Swanson 1984; Bisson et al. 1987). The orientation and size of woody debris can enhance channel and habitat heterogeneity by altering flow direction and velocity (Everest and Meehan 1981). Deposited organic matter provides structure and stability for food resources in most riverine systems (McArthur 1989). Therefore, alterations that limit or remove organic matter or significantly change the nature of these materials affect the productivity, diversity, and stability of aquatic communities. Lower diversity and abundance of strata (e.g., rocks, large woody debris) in and adjacent to flowing water reduce (1) the accumulation and decomposition of organic debris, resulting in decreased production of macroinvertebrates, (2) production of invertebrate and fish biomass by elimination of cover and disruption of orientation and territorial behavior, and (3) prey availability for piscivorous species (Marzolf 1978). Habitat quality for wetland-associated furbearers is degraded when snags, boulders, aquatic and riparian vegetation, and shoreline complexity are reduced (Arner et al. 1976; Gray and Arner 1977; Racey and Euler 1983).

Investigations in riparian communities indicate that abundance and diversity of riparian herpetofauna are dependent on the availability and diversity of microhabitats in large woody debris and litter provided, in part, by seasonal flooding (Jones and Glinski 1985; Jones 1988). Although rapidly fluctuating water levels may be temporarily detrimental to riparian herpetofauna (Warren and Schwalbe 1985), debris deposited by high flows provides microhabitats beneficial to species not immediately dependent on the aquatic portion of the riparian community. Because of reductions in seasonal flooding, density of woody vegetation, and abundance of debris, species richness and abundance of herpetofauna are lower in regulated stream reaches than in reaches with natural fluctuations in discharge.

Debris contributes to habitat structure in the channel by anchoring the position of pools and creating backwaters along the stream boundary and by contributing to lateral migration of the channel (Sedell and Fraggate 1984; Bisson et al. 1987). In higher order streams or in rivers with channels that are too wide for spanning, debris is deposited along channel margins. The highest densities of invertebrates and the most productive fish habitat are in these locations. These sites provide excellent foraging habitat for minks and other wetland-associated furbearers because debris provides cover for prey as well as for hunting predators. Woody debris has a similar influence on the quality of habitat and its use by river otters (*Lutra canadensis*; Melquist and Hornocker 1983). Availability of prey was believed to have the greatest influence on habitat use by river otters in Idaho. However, adequate shelter was required for extensive use of foraging areas. Because they provided ideal cover for foraging and resting, logjams and debris were frequent resting sites and centers of activity for river otters.

Spring-fed Creeks

Spring-fed tributary creeks are an important wetland class in the Snake River floodplain. They provide suitable temperatures and essential spawning habitat for cutthroat trout and other fish species (Kiefling 1978; Simpson and Wallace 1982). The importance and rarity of suitable spawning habitat for cutthroat trout in the upper Snake River drainage was emphasized by Kiefling (1978). Spawning habitat in the main river channel is extremely limited because high flows during spring runoff increase turbidity and sediment loads during the spawning period.

Habitat in spring-fed tributaries on the Snake River floodplain is believed to have deteriorated in area and quality from alterations in seasonal flooding and sedimentation (U.S. Fish and Wildlife Service 1990). These factors in combination with decreased discharge of some spring-fed creeks reduced habitat for all life stages of trout. Conversely, sedimentation and plant succession in spring-fed creeks have been beneficial to other species (e.g., trumpeter swan) by providing wetland cover types suitable for foraging and reproduction. Total dewatering or absence of spring-fed creeks in the floodplain of a given reach of the Snake River is assumed to create lower habitat diversity and a potentially lower richness of wildlife species.

Pool-Riffle Ratio

Pool–riffle ratio is the length or percentage of riffle divided into the length or percentage of pool (Platts et al. 1983). Pools are the deeper, placid, and slower moving sections of a river or stream, whereas riffles are the faster, shallower waters. A ratio of 1:1 is generally believed to provide optimum conditions for fish production and habitat quality (Platts et al. 1983; Marcus et al. 1990). A well-interspersed mix of pools and riffles provides a variety of microhabitats from which numerous aquatic and wetland dependent species benefit. Physical obstruction to water flow increases complexity and productivity of lotic communities by contributing to formation of pools, storage of sediment and organic matter, and provision of cover for invertebrates and vertebrates. Obstructions create pools with deeper water of slower velocity that provide escape cover and promote higher densities of fishes in various age classes (Angermeier and Karr 1984; Sedell and Froggatt 1984; Bisson et al. 1987).

Spatial Relations

The ecological value of wetlands is largely based on their interspersion and physical relation with other plant communities (Mitsch and Gosselink 1986). Resident wildlife species with specific, unique habitat requirements usually have relatively small home ranges that may be within a single wetland community. In contrast, large, wide-ranging species are not restricted to riparian communities, but may be only seasonally dependent on them. Nevertheless, access to and use of riparian communities may be essential to meeting annual habitat requirements of these species.

Landscape modifications that eliminate movement between component subsystems may be as devastating as direct elimination of required critical habitats (Harris 1988). For example, riparian corridors are believed to be important for dispersal of small mammals (Cross 1985; Dickson and Williamson 1988). Ideally, riparian communities are evaluated and managed for their role in a functional landscape mosaic, large enough to provide significant wildlife habitat and capable of resisting detriment from adjacent lands (Harris 1988; Olson and Knopf 1988; Brown 1989). Urbanization and intensive land use tend to produce isolated units of wetland habitat where wildlife and wetland functions face higher susceptibility and lower resiliency to detrimental effects from surrounding land use (Brown 1989). Although riparian communities can be considered biological islands that support fauna and flora of greater species richness and densities than are typical of adjacent communities, the integrity of wildlife values in riparian wetlands cannot be maintained by setting aside reserves and disregarding landscape-level processes.

Corridor width and breaks in the corridor are critical influences of habitat value in a stream corridor (Forman 1983). Fragmentation and elimination of access to critical habitats result in loss of wide-ranging species, reduction of population viability of area-sensitive and interior species, reduction in genetic integrity of species or populations, and enhancement of habitat quality for generalist species of disturbed environments (Brinson et al. 1981; Cooper and Lee 1987). The final result is that riparian communities, and eventually regions, lose distinguishing biological characteristics and acquire already common generalist species (Sampson and Knopf 1982; DeGraff 1986; Harris 1988).

Most forms of landscape degradation can be attributed to reduction in landscape complexity that lowers diversity of plant and animal communities (Bridgewater 1988). The role of riparian habitats in maintenance of regional wildlife values must be addressed if integrity of regional ecosystems is to be maintained (Knopf 1985; Olson and Knopf 1988). Within-habitat (alpha) diversity has received widespread use in wildlife management and in most situations can be expected to be high in structurally diverse riparian communities. However, most measures of alpha diversity do not address the spatial distribution of species or the composition of entire communities. The potential for high levels of wildlife species richness is greater between than within plant communities. Because of their unique attributes, riparian communities of western riverine systems contribute to between habitat (beta) diversity and regional (gamma) diversity. Greater emphasis needs to be placed on techniques that address size, shape, distribution, and linkages of vegetative communities in large geographic areas if wildlife values in riparian ecosystems are to be preserved or enhanced (Odum 1978; Sanderson et al. 1979; Gall and Christian 1984; Harris 1988).

Summary of Riparian Habitat and Wildlife Diversity

A common theme in describing the quality of riparian plant communities as wildlife habitat is physical, vegetative, and spatial diversity. The ability of riparian areas to support diverse and productive wildlife communities is a function of the physical complexity of the water channel and immediate shoreline and of the abundance and diversity of plant communities adjacent to the riverine channel. Actions that modify naturally fluctuating water regimes, eliminate or reduce channel and shoreline diversity, diminish vertical or horizontal vegetative structural complexity, or fragment and isolate riparian communities tend to lower habitat quality for species that are restricted to or are seasonally dependent on riparian habitats.

The role of western riparian wetlands in regional wildlife diversity is less well defined than characteristics of these communities to specific wildlife species. On a landscape level, the role of riparian corridors in dispersal and migration of mammals and birds alone justifies greater protection and enhancement of the unique attributes of these communities. The value of riparian communities to wildlife increases in response to greater divergence in vegetative characteristics between riparian and adjacent vegetative communities. As a result, riparian communities along high order, low elevation riverine cover types probably have the greatest values for wildlife in the intermountain and southwestern United States.

Habitat Suitability Index Model for a Riparian Wildlife Community

Model Overview and Output

This model is designed for a quantitative assessment of the quality of the riparian habitat along the Snake River near Jackson, Wyoming. The model estimates the richness of vertebrate species that are dependent on riparian habitat by comparing vegetation and physical conditions with those that were present along the river in 1956. The assumption is that the wildlife community in 1956 was highly diverse and its abundance patterns approximate historical norms. The output of the model is a measure of the richness of vertebrates that depend on riparian habitat and is based on the assumption that as it increases, richness increases and the pattern of species abundance more closely approximates the 1956 baseline conditions. The quality of riparian habitat can be evaluated for discrete 1.6-km river reaches or for the entire 40 km area. The list of riparian-dependent species (Appendix) was determined from a rating system by Gerhart and Olson (1982).

Model Applicability

Application of the model is restricted to the Snake River near Jackson, Wyoming. The model relies in part on a specific comparison of existing or predicted plant communities with conditions in 1956.

Model Variables and Assumptions

The following sections describe the specific variables for estimating vertebrate species richness with the model. These sections explain the derivation of the variables, including interpretation of the scientific literature and incorporation of workshop results. The model is intended to be applied with remotely sensed data describing the model variables. Adequate data for an empirically based statistical model do not exist.

SIV1—Percentage of 1956 Cover Type

The scientific literature and the workshop participants support the hypothesis that the horizontal and vertical structure provided by a diversity of plant community types and successional stages is the primary factor influencing wildlife species richness in riparian habitats. Workshop participants were concerned that a model output equal to a general measure of species richness might overlook the habitat needs of species with specific needs (e.g., species requiring large stands of mature cottonwood). Therefore, the model is based on comparing existing or expected vegetation patterns with conditions in 1956, and yields existing or expected richness of riparian-dependent species from this comparison. Such a measure avoids the pitfalls of managing for maximum alpha (site-specific) species richness, but should address the needs of species important in maintaining gamma (regional) species richness.

The model variable that assesses vegetation structure is the existing or expected vegetation by cover type expressed as a percentage of the vegetation in 1956. The cover types that are mapped and used for this variable to assess habitat on the Snake River near Jackson, Wyoming, are listed in Table 1. This cover type system was developed by the U.S. Army Corps of Engineers in cooperation with other members of the tri-agency team. The successional stage of woody vegetation is considered in the modifiers for cottonwood stands and the cover types for cottonwood or willow shrub. Future years with lower than 1956 amounts of any particular successional cover type will cause the model to yield lower values of species richness. Each cover type in 1956 is assumed to have made an important contribution to species richness in 1956.

The curve of the suitability index (SI) graph for this variable (SIV1; Fig. 1) is based on species–area relation concepts in community ecology. A general guiding principle in community ecology is that, as the area of a habitat is reduced to one-tenth its original size, the number of species is reduced to one-half (Wilson 1985). The specific shape of this curve is based on species–area relations for birds from 34 shelterbelts in Kansas (Schroeder et al. 1992). Empirical data on species–area relations in Wyoming riparian habitat patches are limited. Gutzwiller and Anderson (1987) provided data on riparian habitat fragments and use by 10 species of cavity nesting birds. A species–area curve with their data did not differ from a species–area curve for cavity nesters in the Kansas shelterbelt data ($P < 0.05$). Therefore, the shape of the species–area curve from the Kansas data is assumed to be adequate for use in this model.

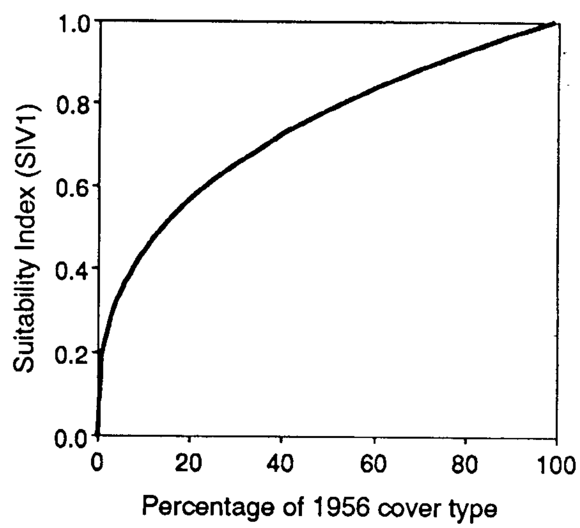

Fig. 1. Suitability index (SIV1)—the relation between the percentage of 1956 cover type and the SI value, determined as: SI = 0.194 × (% of 1956)$^{0.357}$. If the observed cover exceeds 100%, the SI should be set at 1.0.

The shape of the graph in SIV1 indicates that the rate of change in SI values is low for cover types with only small deviations from 1956 cover type percentages and much higher in cover types with extremely large deviations from 1956. Thus, a 20% deviation from 1956, from 100% similarity to 80%, results in an estimated 7% decline in species richness. A similar 20% decline, from 30% to 10% similarity, however, results in an estimated 21% decline in richness. This relation indicates that, although 1956 is the desired condition, minor deviations cause only small changes in the model output. This reflects a concern that percentages of various cover types in a naturally functioning dynamic riparian system vary over time and that only as these differ grossly from 1956 is there a severe effect on species richness. Cover types exceeding the areas in 1956 cannot exceed a 1.0 SI. The total area of each river reach in 1956 (to the outer boundaries of the estimated 500-year floodplain) is used in all computations for other years, irrespective of changes in cover type composition or conversion to upland or urban habitats.

An important aspect of comparing vegetation patterns with 1956 baseline data is the spatial distribution of vegetation along the entire 40-km study area. For purposes of assessing this linear distribution, the variable SIV1 should be applied in each 1.6-km river segment for all cover types. The 1.6-km distance was chosen because the study area had previously been divided into these segments. Workshop participants agreed that, although the distance was somewhat arbitrary, it seemed to be biologically reasonable, given the small home range size of most of the riparian-dependent species of wildlife.

The procedure for computing a suitability index value for this variable (SIV1) involves the following steps:

1. Determine the relative percent abundance of each plant cover type in each river segment for the 1956 baseline condition:

$$\frac{\text{Area of cover type}}{\text{Area of river segment}} = \text{\% of cover type (1956)}$$

2. For the desired year of analysis, determine the relative percent abundance of each cover type in each river segment:

$$\frac{\text{Area of cover type}}{\text{Area of river segment}} = \text{\% of cover type (year of analysis)}$$

3. Compare the percent occurrence of each cover type for the desired year of analysis with the percent 1956 baseline for that cover type. Convert this to a percentage:

$$\frac{\text{\% cover type (year of analysis)}}{\text{\% cover type (1956)}} \times 100 = \text{\% of 1956 (for year of analysis)}$$

4. Put the percent of 1956 (for year of analysis) for each cover type into the formula for the graph for SIV1 and determine the SI value for each cover type.
5. Determine an area-weighted SI by multiplying the value for SIV1 for each cover type by the decimal equivalent of the percentage cover type (1956; determined in step 1) for that cover type. (For example, if a cover type had 50% abundance in 1956, use the decimal 0.5.)
6. Sum the values from step 5 for all cover types in the river segment being analyzed. This sum is the overall value for SIV1 for this segment.

For further details on applying this variable, refer to the sample data sets and calculations in the section *Habitat Suitability Index Determination and Application of the Model.*

SIV2—Channel and Floodplain Complexity

The workshop participants and pertinent literature support inclusion of a variable to assess physical complexity of the channel and floodplain for assessment of habitat quality in riparian communities. Factors deemed important by workshop participants included the presence or absence of overbank flooding, sediment-free spring-fed creeks, physically complex shoreline, high pool–riffle ratios, braided channels, oxbows, and islands. All of these factors contribute to defining a river system that is dynamic and influenced by fluctuations in discharge and seasonal distribution of water throughout the floodplain.

The suitability index for this variable (SIV2) is determined by summing a single value for each of the six factors of channel and floodplain diversity.

Factor	Index
1. Channel configuration	
a. main channel braided or meanders throughout erosional floodplain; oxbows, side channels, or other nonriverine wetland types are present in the evaluated reach	0.2
b. single channel; reach is relatively straight; portions of the channel are contained in dikes to prevent lateral movement of main channel in floodplain; other wetland types not present in the evaluated reach	0.1
c. entire reach is channelized; river is confined on both sides to prevent lateral movement in floodplain	0.0
2. Dynamically stable islands	
a. islands are present within annual boundaries of main channel; islands of various size supporting full spectrum of vegetation succession ranging from newly deposited, unvegetated sediment to islands dominated by mature stands of riparian vegetation (e.g., willow and cottonwood)	0.2
b. islands are present within annual boundaries of main channel, vegetation communities on islands are skewed to one end of successional spectrum (e.g., majority in mature class or composed of newly deposited, unvegetated sediment)	0.1
c. islands absent in the evaluated reach	0.0
3. Overbank flooding	
a. high potential for seasonal overbank flooding, channel not confined by artificial barriers (e.g., dikes and levees)	0.2
b. moderate potential for seasonal overbank flooding; one side or segments of channel confined by dikes or levees	0.1
c. little to no potential for seasonal overbank flooding; entire channel in evaluated reach is channelized	0.0
4. Spring-fed creeks	
a. present, diverse substrate composition	0.2
b. present, more homogenous substrate composition	0.1
c. absent	0.0
5. Shoreline complexity	
a. presence of undercut banks, large woody debris (e.g., root wads, tree trunks, and debris piles) im-	

mediately adjacent to channel and in the water column; vegetated banks in immediate proximity to water; diversity of substrate types (e.g., silt, sandbars, gravel, cobble, and boulders) compose land–water interface 0.1

b. shoreline essentially straight, open and exposed (i.e., channelized and levee) with abrupt monotypic edge between water and land; little to no diversity in substrates at land–water interface; few to no physical or vegetation features that provide structure or cover in or in close to water 0.0

6. Pool–riffle ratio
   a. good, area in pools and riffles approximately equal 0.1
   b. poor, highly uneven distribution of either pools or riffles–runs 0.0

Total score (0–1.0) ___

These factors and their perceived importance to the wildlife community were weighted by participants of the workshop. Although some degree of intercorrelation of the above factors is probable, the participants decided to include all factors to assure an adequate overall view of physical complexity. This variable should be applied by computing an SI value for each river segment and averaging them for the entire study area. The average SIV2 for 1956 conditions is assumed to be the best attainable condition, and overall average conditions following 1956 and the influence of the levees should always be of lower quality. Suitability index values for an individual river segment could exceed the SI of that segment for 1956. The overall average condition of channel and floodplain complexity is assumed to be more important than a spatial distribution of these features equal to 1956.

SIV3—Percentage of River Reach Subject to Human Disturbance

The ability of riparian wildlife species to move freely and disperse along the riparian corridor is important to the long-term maintenance of wildlife species richness. Workshop participants and the scientific literature indicate that excessive human disturbance can have a negative influence on wildlife in riparian habitats.

Human disturbance is assumed to have two major effects: (1) direct loss of use of habitat in and near areas of disturbance, and (2) disruption of movement patterns of wildlife along the narrow riparian corridor. The effects of human disturbance on wildlife are difficult to quantify. Certain species and, in some cases, certain individuals in a species, respond differently to human disturbances. The effects of human disturbances often extend beyond the boundaries of the area where the disturbance is effected. We assume that disturbances are in one of three categories and that more severe disturbances affect habitat use and wildlife movement in a larger surrounding zone as delineated in Table 2.

The distances provided for the additional zone of influence are based on data about disturbed bald eagles (McGarigal et al. 1991). A buffer zone of approximately 100 m (328 feet) was estimated to protect 50% of the breeding eagle population from flushing by human disturbances. The suitability index for assessing the effects of human disturbance (SIV3) is illustrated in Fig. 2. The percent of the disturbed river reach is determined by combining the actual disturbed area and the area in the surrounding zone of influence for each disturbance and computing a percentage of the disturbed reach. As this percentage increases, the SI value is assumed to linearly decrease, reaching

Table 2. *Level and extent of influence of human activities on wildlife habitat.*

Level of disturbance	Examples of activities or land uses	Additional zone of influence
High	Industry, commercial development, high density residential (>1 unit per 1.2 ha) development, paved highway, active quarry	100 m
Medium	Levee with public access, golf course, low density residential (<1 unit per 1.2 ha) development, gravel road, inactive quarry, cropland	50 m
Low	Dirt road, levee with limited access, recreation areas, rangeland, native pasture	0 m

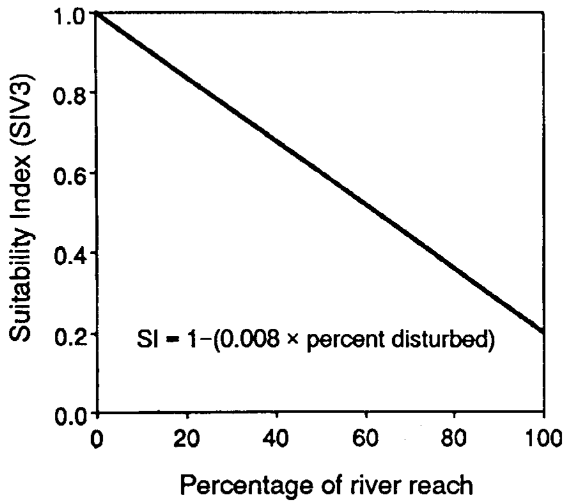

Fig. 2. Suitability index (SIV3)—the relation between the percentage of disturbed river reach and the SI value.

a worst case value of 0.2 at 100%. Twenty percent of the riparian dependent native species (Appendix) are assumed to tolerate a high level of human disturbance and continue to occupy highly disturbed river reaches.

Habitat Suitability Index Determination and Application of the Model

Application of the model requires the computation of an intermediate value for SIV1, SIV2, and SIV3 along each 1.6-km river reach segment. Overall HSI determination then uses the averages of the SI values for all reaches. Separate HSI values are not computed for each river reach. Vegetation structure is assumed to be a more important determinant of species richness than channel complexity. Therefore, SIV1 is weighted in the HSI formula. The overall HSI for the entire study area is computed as follows:

$$\text{Study area HSI} = \frac{2(SIV1) + (SIV2)}{3} \times (SIV3)$$

The following sample data set illustrates how to apply the model and calculate river segment SIs and the overall HSI. Any modifications of the original model should be accompanied by further analysis of sample data sets to ensure appropriate response in the model.

SIV1—Structure and Abundance of Riparian Vegetation.

Step 1. Determine relative percentage of cover types for 1956.

Cover type	Assumed 1956 area (ha)	Relative %
Riparian cottonwood (>40 feet, >70%)	100	50
Palustrine scrub-shrub wetland, willow	60	30
Palustrine emergent wetland	20	10
Riverine	20	10
Total	200	100

Step 2. Determine relative percentage of cover types for year of analysis.

Cover type	Year of analysis area (ha)	Relative %
Riparian cottonwood (>40 feet, >70%)	40	20
Palustrine scrub-shrub wetland, willow	40	20
Palustrine emergent wetland	10	5
Riverine	20	10
Upland grassland	90	45
Total	200	100

Step 3. Compare year of analysis with 1956.

Cover type	Year of analysis %	1956 %	% of 1956
Riparian cottonwood	20	50	40
Palustrine scrub-shrub wetland, willow	20	30	67
Palustrine emergent wetland	5	10	50
Riverine	10	10	100
Upland grassland[a]	45	0	NA

[a] Upland grassland is not considered because it did not occur in the river reach in 1956.

Step 4. Determine SIV1 from suitability index graph and formula. Put percentage of 1956 cover type (use the whole number) in the formula and calculate SI.

Cover type	SIV1
Riparian cottonwood	0.72
Palustrine scrub-shrub wetland, willow	0.87
Palustrine emergent wetland	0.78
Riverine	1.00
Upland grassland	NA

Step 5. Multiply the SI for each cover type by the percentage of 1956.

Cover type	SIV1		1956 %		Weighted SI
Riparian cottonwood	0.72	×	50	=	0.36
Palustrine scrub-shrub wetland, willow	0.87	×	30	=	0.26
Palustrine emergent wetland	0.78	×	10	=	0.078
Riverine	1.00	×	10	=	0.1
Upland grassland	NA				

Step 6. Determine the overall value for SIV1 in the river segment.
Sum of weighted SIs from step 5 = SIV1 = 0.798

SIV2—Channel and Floodplain Complexity

Factor	Index	River segment score
1. Channel configuration		
a. main channel braided or meanders throughout erosional floodplain, oxbows, or side channel or other nonriverine wetland types are present in reach being evaluated	0.2	
b. single channel reach is relatively straight, portions of the channel are contained in dikes to prevent lateral movement of main channel in floodplain, other wetland types not present in reach being evaluated	0.1	
c. entire reach is channelized, river confined on both sides to prevent lateral movement in the floodplain	0.0	0.0
2. Dynamically stable islands		
a. islands are present in annual boundaries of main channel, islands of various size supporting full spectrum of vegetation succession range from newly deposited, unvegetated sediment to islands dominated by mature stands of riparian vegetation (e.g., willow, cottonwood)	0.2	
b. islands are present in annual boundaries of main channel; vegetation communities on islands are skewed to one end of successional spectrum (e.g., majority in mature class or composed of newly deposited, unvegetated sediment)	0.1	
c. islands absent in the evaluated reach	0.0	0.2
3. Overbank flooding		
a. high potential for seasonal overbank flooding, channel not confined by artificial barriers (e.g., dikes, levees)	0.2	
b. moderate potential for seasonal overbank flooding, one side, or segments or channel confined by dikes or levees	0.1	
c. little to no potential for seasonal overbank flooding; the entire channel in evaluated reach is channelized	0.0	0.0
4. Spring-fed creeks		
a. present, diverse substrate composition	0.2	
b. present, more homogenous substrate composition	0.1	
c. absent	0.0	0.1
5. Shoreline complexity		
a. presence of undercut banks, large woody debris (e.g., root		

wads, tree trunks, debris piles) immediately adjacent to channel and in the water column; vegetated banks in immediate proximity to water; diversity of substrate types (e.g., silt, sandbars, gravel, cobble, boulders) compose land–water interface	0.1	
b. shoreline essentially straight, open and exposed (i.e., channelized, levee) with abrupt monotypic edge between water and land; little to no diversity in substrates at land–water interface; few to no physical or vegetation features that provide structure or cover in or in close proximity to water	0.0	0.0
6. Pool–riffle ratio		
a. good, area in pools and riffles approximately equal	0.1	
b. poor, highly uneven distribution of either pools or riffles–runs	0.0	0.0

Total score SIV2 (0–1.0) = 0.3

SIV3—Spatial Relations and Human Disturbance

	Percent	SIV3
Percentage of river reach subject to human disturbance	20	0.84

Study Area HSI

Use average values for SIV1, SIV2, and SIV3 for all river reaches of concern. In this example, only one reach is used.

$$\frac{2(\mathrm{SIV1}) + (\mathrm{SIV2})}{3} \times (\mathrm{SIV3}) = \frac{2(0.798)+0.3}{3} \times 0.84 = 0.53$$

The final HSI value of 0.53 indicates a riparian habitat that supports approximately one-half the number of riparian-dependent species as the same area in 1956.

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Appendix. Riparian-dependent vertebrates from the region of the Snake River near Jackson, Wyoming[a]

Common name	Scientific name
Amphibians	
Tiger salamander	*Ambystoma tigrinum*
Boreal chorus frog	*Pseudacris triseriata maculata*
Northern leopard frog	*Rana pipiens*
Spotted frog	*Rana pretiosa*
Reptiles	
Wandering garter snake[b]	*Thamnophis elegans vagrans*
Valley garter snake[b]	*Thamnophis sirtalis fitchi*
Birds	
Great blue heron	*Ardea herodias*
Green-backed heron	*Butorides striatus*
Wood duck	*Aix sponsa*
Northern pintail	*Anas acuta*
American widgeon	*Anas americana*
Northern shoveler	*Anas clypeata*
Green-winged teal	*Anas crecca*
Cinnamon teal	*Anas cyanoptera*
Blue-winged teal	*Anas discors*
Mallard[b]	*Anas platyrhynchos*
Gadwall	*Anas strepera*
Lesser scaup	*Aythya affinis*
Redhead	*Aythya americana*
Ring-necked duck	*Aythya collaris*
Bufflehead	*Bucephala albeola*
Common goldeneye	*Bucephala clangula*
Barrow's goldeneye	*Bucephala islandica*
Trumpeter swan	*Cygnus buccinator*
Harlequin duck	*Histrionicus histrionicus*
Hooded merganser	*Lophodytes cucullatus*
Common merganser	*Mergus merganser*
Ruddy duck	*Oxyura jamaicensis*
Osprey	*Pandion haliaetus*
Broad-winged hawk	*Buteo platypterus*
Bald eagle	*Haliaeetus leucocephalus*
American coot[b]	*Fulica americana*
Spotted sandpiper[b]	*Actitis macularia*
Yellow-billed cuckoo	*Coccyzus americanus*
Black-billed cuckoo	*Coccyzus erythropthalmus*

Appendix A. *Continued.*

Common name	Scientific name
Willow flycatcher	*Empidonax traillii*
Great crested flycatcher	*Myiarchus crinitus*
Bank swallow[b]	*Riparia riparia*
Northern rough-winged swallow[b]	*Stelgidopteryx serripennis*
Marsh wren	*Cistothorus palustris*
American dipper[b]	*Cinclus mexicanus*
Black-throated blue warbler	*Dendroica caerulescens*
Bay-breasted warbler	*Dendroica castanea*
Blackburnian warbler	*Dendroica fusca*
Palm warbler	*Dendroica palmarum*
Common yellowthroat	*Geothlypis trichas*
Yellow-breasted chat	*Icteria virens*
MacGillivray's warbler	*Oporornis tolmiei*
American redstart	*Setophaga ruticilla*
Wilson's warbler	*Wilsonia pusilla*
Summer tanager	*Piranga rubra*
Indigo bunting	*Passerina cyanea*
Lincoln's sparrow	*Melospiza lincolnii*
Song sparrow[b]	*Melospiza melodia*
Field sparrow	*Spizella pusilla*
White-crowned sparrow[b]	*Zonotrichia leucophrys*
American goldfinch[b]	*Carduelis tristis*
Masked shrew	*Sorex cinereus*
Mammals	
Northern water shrew	*Sorex palustris*
Vagrant shrew	*Sorex vagrans*
Mink	*Mustela vison*
River otter	*Lutra canadensis*
Moose	*Alces alces*
White-tailed deer	*Odocoileus virginianus*
Beaver	*Castor canadensis*
Montane vole[b]	*Microtus montanus*
Meadow vole[b]	*Microtus pennsylvanicus*
Water vole	*Microtus richardsoni*
Muskrat[b]	*Ondatra zibethicus*
Western jumping mouse	*Zapus princeps*

[a] Adapted from Gerhart and Olson (1982) and U.S. Fish and Wildlife Service (1990).

[b] Species assumed to tolerate high levels of human disturbance.