MODELING RISKS TO BIODIVERSITY IN PAST, PRESENT AND FUTURE LANDSCAPES

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ABSTRACT

Methods for assessing potential impacts of human activities on biodiversity across a hierarchy of spatial and temporal scales are useful for making land use planning clearer and better informed. We examined risks to vertebrate biodiversity by comparing present landcover to that in the Pre-Settlement past and in alternative future land use scenarios for the western Muddy Creek watershed (320 km^2) in the Willamette River basin in Oregon. A map of present landcover was derived from remote sensing with some ground truthing. Landcover maps for five scenarios for the year 2025 were envisioned in consultation with stakeholders in the watershed. A map of Pre-Settlement landcover was reconstructed by Oregon state agencies from Government Land Office survey records from the 1850s. In consultation with local experts, we compiled historical and current species lists for the watershed during the breeding season (including 135 bird, 71 mammal, 16 reptile and 14 amphibian species), and a species-habitat association matrix. Of the 236 species, 1 amphibian, 3 bird and 4 mammal species were permanently extirpated; 8 bird and 2 mammal species native to the watershed were deemed rare (including currently extirpated); 1 amphibian, 1 reptile, 6 bird and 6 mammal species were introduced. Risks for each species were calculated from the percentage of habitat area in the Pre-Settlement past and in each future compared to the present, and then summarized across all species, and species grouped by conservation and management interest. For all native species, risk was greatest in the High-Development future at 19% worse than present, and consistently declined across futures, with the High-Conservation future 6% better than the present; the Pre-Settlement past was 9% better than the present. The trend across futures was similar for all taxa except reptiles which had little change; amphibians changed most dramatically. Reptiles had the greatest loss (65%) from Pre-Settlement to present. For rare species and for vulnerable species (endangered, threatened, etc.), the High-Conservation future was 10% and 13% better, and the High-Development future was 38% and 36% worse than present, respectively; the present was 112% and 25% worse than Pre-Settlement, respectively. Forty-one native species were at risk of losing at least 50% of their habitat in one or more of the futures compared to 27 species from the Pre-Settlement to the present; only three species were in common, suggesting that habitat changes from Pre-Settlement to the present are different than those envisioned for the futures. For more information on the Muddy Creek project and colour graphics for this report, view the World Wide Web at [http://ISE.uoregon.edu].

Keywords: biodiversity, risk assessment, landuse planning, temporal trends

RÉSUMÉ

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Estimation du risque à la biodiversité évaluée pour des paysages pré-colonisation, présent et futurs

Les méthodes pour estimer les impacts potentiels des activités humaines sur la biodiversité à plusieurs niveaux hiérarchiques spatiaux et temporels sont utiles pour une planification de l'utilisation des terres qui soit meilleure et plus informée. Nous avons exammíné les risques pour la biodiversité des vertébrés en comparant le degré actuel de couverture des terres à la couverture des terres de la période pré-colonisation de même qu'à differentes alternatives hypothétiques de développement futur. Ceci a été effectué pour le bassin versant ouest de Muddy Creek (320 km carré) faisant partie du bassin de la rivière Willamette en Orégon. Un carte présentant la couverture des terres a été effectuée à partir de photos satellites et quelques vérifications sur le terrain. Des cartes représentant la couverture des terres pour cinq scénarios différents de l'an 2025 ont été conçues en consultation avec des propriétaires et différents intervenants du bassin versant en question. Une carte définissant la couverture des terres avant la colonisation, à partir des années 1850, fut reconstruite par des agences de l'état de l'Orégon à partir de données de surveillance de l'Office des Terres du Gouvernement (Government Land Office). En consultation avec des experts locaux, nous avons dressé une liste historique, puis une liste des espèces que l'on retrouve présentement dans le bassin versant durant la saison de reproduction (la liste inclue 135 espèces d'oiseaux, 71 mammifères, 16 reptiles, et 14 amphibiens) de même qu'une matrice situant les espèces dans leurs habitats. Des 236 espèces, 1 espèces d'amphibien, 3 espèces d'oiseaux and 4 mammifères ont été extirpés de façon permanente; 8 espèces d'oiseaux et 2 espèces de mammifères indigènes au bassin versant furent considérées rares (incluant celles aujourd'hui extirpées); 1 espèce d'amphibien, 1 reptile, 6 espèces d'oiseaux et 6 mammifères ont été introduits. Les risques pour chaque espèce ont été calculés à partir du pourcentage de la surface en habitat estimée pour la période pré-colonisation comparée avec l'aire présente et celle de chacun des scénarios envisagés pour le future, puis ces calculs ont été résumés pour toutes les espèces de même que pour les espèces groupées selon des valeurs de conservation et de gestion. Pour toutes les espèces indigènes, le risque était plus grand dans le scénario futur où le développement était le plus élevé, i.e. 19% pire que le présent; le risque diminuait régulièrement à mesure qu'on se rapprochait du scénario futur à conservation élevée, 6% meilleur que celui d'aujourd'hui. Pour tous les scénarios futurs la tendance était similaire et ce, pour tous les taxons sauf les reptiles où il y avait très peu de changement; les amphibiens ont changé le plus. Les reptiles ont subi les plus grandes pertes (65%) de la période pré-colonisation à aujourd'hui. Pour les espèces rares et les espèces vulnérables (en danger, menacées, etc.), le scénario du future avec le plus haut niveau de conservation était meilleur pour ces espèces de 10 et 13%, respectivement. Par contre le scénario avec le plus haut niveau de développement était pire pour ces espèces de 38% et 36% par rapport au présent; le présent était 112% et 25% pire par rapport à la période pré-colonisation, respectivement. Quarante et une espèces indigènes étaient en danger de perdre au moins 50% de leur habitat dans un ou plusieurs scénarios futurs comparativement à 27 espèces d'avant la colonisation par rapport au présent; de ces espèces seulement trois espèces étaient communes, ce qui suggèrent que les changements dans les habitats de la période pré-colonisation par rapport à la période présente sont différents de ceux imaginés pour les différents scénarios futurs. Pour de plus amples informations sur le projet Muddy Creek de même que pour obtenir des graphiques en couleur pour ce rapport, se referer au site au système d'information planétaire (World Wide Web): [http://ISE.uoregon.edu].

Mots clés: biodiversité, estimation de risque, planification de l'utilisation des terres, tendances temporelles

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INTRODUCTION

Maintaining biodiversity is important for supplying vital resources (food and pharmaceuticals), providing economic income and stability, ensuring long-term ecosystem viability, and for ethical considerations such as intrinsic value (e.g. Wilson 1988, Heywood and Watson 1995). Land-use practices are a major cause of the decline in biodiversity in recent decades (Soulé 1991, World Conservation Monitoring Center 1992, p. 235). Conservation efforts have focused on maintaining biological diversity primarily by minimizing exposure to human activities through establishment of networks of protected areas (e.g. Scott et al. 1987, 1993). However, the long-term conservation of biological diversity is dependent not only on establishment of protected areas, but also on maintaining hospitable environments and viable populations within human-dominated landscapes (Noss and Harris 1986, Western 1989, Hansen et al. 1991, Shafer 1994, Freemark et al. 1995).

The Muddy Creek referred to in this report lies just west of the Willamette River in Benton County, western Oregon (Figure 1; an entirely separate Muddy Creek lies just east of the Willamette River). We modeled the impacts of past and possible future landscape changes on the biodiversity of the 320 km^2 Muddy Creek watershed. This modeling approach, developed by White et al. (in press), requires a GIS habitat map for each landscape scenario (past, present, and alternative futures), a list of resident species, and the species' associations with the habitat classes on each map. We modeled biodiversity as breeding amphibian, reptile, bird, and mammal species in the watershed (Tables 1 and 2). See Scott et al. (1993) for a justification for using non-fish vertebrates to represent total biodiversity.

Land cover data for the present and possible futures of the Muddy Creek watershed were provided by the University of Oregon research team. The data included a present-day land cover map of the watershed (Figure 2) derived in part from air photo analysis by the Oregon Department of Fish and Wildlife and from satellite multi-spectral imagery analysis (Cohen et al. 1995). Maps of five possible future land cover scenarios for the year 2025 (Figures 3 - 7) were envisioned by the University of Oregon team, in consultation with interested persons from the watershed ("stakeholders"). A map of Pre-Settlement vegetation classes was reconstructed by the Oregon Natural Heritage Program and The Nature Conservancy (ONHP/TNC) from Government Land Office survey records (Figure 8) (John Christy, personal communication 1996). The Pre-Settlement map served a dual purpose in modeling the impact of habitat change on biodiversity: (1) this map allowed for an evaluation of the habitat changes between the past and the present, and (2) this map provided a landscape scenario that could be evaluated (in total, or individual habitat classes) as a 6th potential target for the future of the Muddy Creek watershed. Color versions of these maps (Figures 2 - 8) can be viewed on the World Wide Web at [http://ise.uoregon.edu].

Risk to biodiversity was calculated from ratios of habitat area in each future scenario (and in the past) to habitat area in the present. We calculated risks for individual species, and mean risk for all species and for subsets of species. This measure of change in biodiversity is one estimate of change in species populations. More detailed life history requirements of species (e.g. habitat quality, minimum area requirements) were not incorporated in the model because these data were not available for all species. However, in an earlier study, White et al. (in press) found minimal changes to risk results when area requirements were included.

METHODS

Compiling the list of breeding species

We consulted multiple sources in compiling a vertebrate species list for the Muddy Creek watershed, which includes information for each species about native versus introduced origin, present-day versus past occurrence in the watershed, and season(s) of occurrence in the watershed. The biodiversity modeling was subsequently limited to breeding species, based on their breeding-season association with breeding and feeding habitats, for several reasons. First, habitat use is different between seasons for some species; second, species' breeding-season habitat associations are more readily available than wintering habitat associations; third, the species list for the non-breeding season is different, particularly for migratory birds. Fish were included in the initial working species list, but not in the biodiversity modeling because available landscape data do not adequately represent fish habitat. Humans, both native (now locally extirpated) and more recent immigrants, should also be considered part of a complete breeding species list for the Muddy Creek watershed. Humans were not included in the biodiversity modeling because human population and resource use are the cause (or input variable) of landscape changes, not the result.

We compiled an initial working species list of amphibians, reptiles, birds, and mammals from two primary sources: (1) the Biodiversity Research Consortium (BRC) species database (Master 1995) for the three hexagons that cover 99.1% of the watershed (26967 - 70.8%, 27072 - 4.7%, 27073 - 23.6%; Figure 1); and (2) the Oregon Species Information System (OSIS; Oregon Department of Fish and Wildlife) species list for Benton County, Oregon. The BRC database included information for each species in each hexagon about certainty of occurrence, season of occurrence, breeding versus non-breeding, and native versus introduced origin. The OSIS database included information on each species' native versus introduced origin, and federal and state status (e.g. endangered, threatened, sensitive, game species).

Several additional sources representing a subset of the species or of the watershed area were also compiled: (1) the Breeding Bird Atlas data for the calendar year 1995 (Paul Adamus, personal communication 1996); (2) vertebrate species checklists for Finley National Wildlife Refuge, which is wholly contained in the study area (see also Merrifield 1996); and (3) the Christmas Bird Count data for the Corvallis site, 1984 - 1994, from the National Audubon Society's Birds of America (used to compile an initial list of year-round birds; not used for the final breeding bird list). Historical sources (Bailey 1936, Gabrielson and Jewett 1940, Storm 1941, Storm 1948, Davies 1980, Gilligan and Rogers 1994, Zybach in prep.) were consulted to ensure that the working species list was complete. We also used these historical sources to identify species that have become locally extirpated since European settlement began in the mid-1800s. Contradictory taxonomic nomenclature was clarified with Collins (1990), Jones et al. (1992), American Ornithologists' Union (1995), and local vertebrate biologists.

The working species list for the Muddy Creek watershed (Table 2) was revised through consultation with local vertebrate biology/ecology experts (Table 3), who also assigned each species to one of the following categories: (1) species currently occurs and breeds in the watershed, (2) species is locally extirpated (rare or unlikely breeder) in the watershed but might breed successfully with habitat improvement (R on Table 2), (3) species is permanently extirpated from the watershed and surrounding areas, and will not return even with favorable habitat management (E on Table 2).

Stakeholders viewed and commented on the revised species lists at joint meetings held with the research teams. Several stakeholders responded with queries about the inclusion or exclusion of a species. We consulted with local experts and/or publications to resolve each case.

Red-shouldered Hawk *(Buteo lineatus)*. A stakeholder questioned our inclusion of the Red-shouldered Hawk as a locally extirpated species on the list of breeding birds. Several sources (Gabrielson and Jewett 1940, Peterson 1990, Gilligan and Rogers 1994; Paul Adamus, personal communication 1996) suggest that this species was not historically found in the Willamette Valley. It is now slowly expanding its range into parts of western Oregon. Nests have been documented in several localities in the interior valleys of western Oregon, but not in the Muddy Creek watershed. The Red-shouldered Hawk was removed from the breeding bird list for the Muddy Creek watershed.

Western Meadowlark *(Sturnella neglecta)*. A stakeholder asked why this species had been designated as an "R" (locally extirpated, rare/uncommon breeder) species, when it is still seen in the watershed. Local bird experts had suggested that the Western Meadowlark be categorized as a rare (R) species to reflect the dramatic reductions in its western Oregon populations in recent years. We revised this species' assignment to presently breeding in the watershed, to be more consistent with other species' assignments.

Buffalo *(Bison bison)*. Two stakeholders questioned whether buffalo should be added to the species list as an extirpated species, based in part on one stakeholder's recollection of a newspaper article from several years before. We consulted the article (Baur 1993), along with William Orr (Department of Geology, University of Oregon), who was cited in the article. Buffalo were left off the species list because there is no direct evidence that this species ever lived naturally in the Willamette Valley. There are no documented skulls or bones from any buffalo that lived naturally in the Willamette Valley (Bailey 1936; William Orr, personal communication 1996; Doug Cottam, personal communication 1996).

Marten *(Martes americana)*. A stakeholder questioned whether martens live in the Coast Range in central Oregon. Several sources (Bailey 1936; Marshall 1992; Neil Ten-Eyck, Oregon Department of Fish and Wildlife, personal communication 1996) document the presence of a marten population in the central Oregon Coast Range. The marten was kept on the species list.

Yellowbelly Marmot *(Marmota flaviventris)* and Antelope *(Antilocapra americana)*. A stakeholder indicated that marmots did not occur in western Oregon. We had briefly considered the yellowbelly marmot and the antelope as possible extirpated species, based on a species list cited in Storm (1941, p. 25), whose context suggested that it applied to the Willamette Valley. In the original reference, however, these species were in a list that appears to apply to the entire state of Oregon. There are no other known sources that indicate the presence of either species in the Willamette Valley, and they were both removed from the list.

The final breeding species list for the Muddy Creek watershed (Tables 1 and 2) has 236 species, including 204 present-day native breeding species, 14 introduced species (I), 10 rare species (R), and 8 permanently extirpated native species (E). The list includes 14 amphibians, 16 reptiles, 135 birds, and 71 mammals.

<u>Creating species-habitat associations</u>

We reviewed published and unpublished literature and data to determine species' use of habitats during the breeding season, for breeding and/or feeding. We assigned a "1" (species is likely to use the habitat) or a "0" (species is unlikely to use the habitat) for each entry in the matrix of 26 wildlife habitats and 236 species, for a total of 6,136 species-habitat entries (Table 4). Each source of habitat associations dealt with one of the following combinations: all vertebrates and all habitats (6 sources: Adams and Geis 1981, Brown 1985, Puchy and Marshall 1993, Csuti 1995, Mellen et al. 1995, O'Neil et al. 1995), all vertebrates and a subset of habitats (4 sources: Timm 1983, Ruggiero et al. 1991, Budeau and Snow 1992, Strik and deCalesta 1992), a subset of vertebrates and all habitats (3 sources: Nussbaum et al. 1983, Leonard et al. 1993, Andelman and Stock 1994), or a subset of vertebrates and a subset of habitats (13 sources: Evenden et al. 1950, Anderson 1970, Garman 1992, Bryce 1993, Hansen et al. 1993, Stern 1994, Best et al. 1995, Blaustein et al. 1995, Christian 1995, Hanowski and Niemi 1995, Hansen et al. 1995, McGarigal and McComb 1995, Adamus and Freemark 1996).

Most habitat-association sources were compiled for habitats in western Oregon, and 6 sources presented data from within the Muddy Creek watershed (Evenden et al. 1950, Anderson 1970, Budeau and Snow 1992, Bryce 1993, Stern 1994, Adamus and Freemark 1996). For habitats with little or no Oregon data (e.g. the agricultural habitats), 6 sources outside of Oregon were consulted (Timm 1983, Best et al. 1995, Christian 1995, Hanowski and Niemi 1995, Christian et al. in press, Hanowski et al. in press). Even the most comprehensive sources (attempting to cover all species and all habitats) were not complete, leaving some species-habitat entries blank, due to omission of some species and/or some habitats.

The sources of habitat associations were quite varied in the type of data presented. Some sources presented raw data (e.g. observations of species within habitats), while others presented a summary based on a combination of data and expert opinion. There was also variation in how the sources defined habitat use or association during the breeding season. Most sources used one or more of: general/unspecified use, breeding, feeding, resting, perching. We compiled habitat associations for habitats essential for successful breeding (breeding and/or feeding habitats).

We compiled a list of the data sources that contributed to each of the 26 wildlife habitats. There were between 1 and 10, with an average of 5 data sources for each wildlife habitat. The agricultural habitats had an average of only 3 sources each, with many sources applying to only a subset of the species list. After compiling the data sources, about 15% of the species-habitat entries had no data; most of these information gaps were in the agricultural habitats. For entries that had data, the sources were contradictory in some cases. Local experts (Table 3) were consulted in order to fill in missing species-habitat entries, to resolve entries with contradictory data, and to confirm or modify entries determined from the published sources.

Cross-referencing between mapped land cover and wildlife habitat classes

To identify the habitats that each species uses in the breeding season, we first compiled a list of wildlife habitats that occur in the Muddy Creek watershed. To compile this list we created a cross-reference between: (1) land cover classes for the present and five possible future maps; (2) wildlife habitat classes (data from wildlife publications); and (3) Pre-Settlement vegetation classes (Table 5). Creating this cross-reference (Table 6) involved working within the different constraints of these three data sets. Our task was to find a balance between enough detail to capture differences between species' habitat associations, and enough generalization to have a concise set of habitats. The land cover maps are constrained by the minimum mapping unit size (pixels of 30 meters x 30 meters), which does not allow the inclusion of some habitat variables, such as small riparian or wet areas and scattered woody vegetation at field edges. In addition, the Pre-Settlement vegetation map was compiled from surveyors' notes from the 1850s based on observations along the grid of section lines that lie one mile apart. These observations were then interpolated by ONHP/TNC to the landscape between the section lines, resulting in a map with lower spatial precision and lower accuracy than the present and future land cover maps. We acknowledge these differences in resolution and land cover definitions between the Pre-Settlement map and the other maps, and caution our interpretations accordingly.

Several refinements were required to improve the way that the land cover classes represented wildlife habitats. Initially, there was one combined class for Christmas trees, orchards, and vineyards. Because of the different species associated with these three habitats, they were split apart after roadside mapping in the watershed. Another problem occurred between roads as land cover and roads as wildlife habitat. Roads are mapped throughout the watershed, but the herbaceous roadside habitat only applies to lowland valley roadside habitats. Two road classes (primary roads and secondary highways) only occur in the lowlands, and the herbaceous roadside species were assigned to these roads. We split light duty and unimproved roads into upland and lowland habitats (see section below on modifying land cover maps), and herbaceous roadside species were assigned only to the lowland roads.

Water habitats (1st order streams, intermittent streams, 2+ order streams, open water) were also split into lowland and upland habitats, because while some species are associated with these habitats throughout the watershed, others are only associated with the upland Douglas-fir dominated landscape, or with the open lowland valley landscape. These four water habitats were split into four upland and four lowland habitats (see section below on modifying land cover maps). Another change was made for species associated with water. Species such as the Great Blue Heron *(Ardea herodias)* and the beaver *(Castor canadensis)* use water, as well as forest habitats that are close to water. In the biodiversity model, the habitat available to these species would be underestimated by counting only the water, but it would be overestimated by counting the water plus all the forest. We divided all habitats into near-water and away-from-water (see section below on modifying land cover maps), allowing the 21 species that use near-water habitats (e.g. Great Blue Heron and beaver; "B" in Table 2) to be counted near-water, but not away-from-water.

After these habitat refinements, there were 26 different wildlife habitat classes that were cross-referenced to 38 land cover classes, and to 22 Pre-Settlement vegetation classes (Table 6). There were also an equal number of near-water classes that were cross-referenced. In several cases, a wildlife habitat class was assigned to more than one land cover class (e.g. the herbaceous roadside habitat is assigned to 4 different lowland road classes; urban habitat is assigned to commercial areas and to rural structures). Several land cover classes (e.g. trails; intermittent streams of the lowland) have no habitat associated with them ("Not wildlife habitat" in Table 7), because the surrounding land cover classes would determine the species that are present. The youngest three Douglas-fir forest land cover classes (0-40 yrs, 40-80 yrs, 80-120 yrs) had no equivalent in the Pre-Settlement vegetation classes, according to the surveyors notes, which indicated a wide range of tree ages in each forest patch, and no burned areas.

Modifying land cover maps to represent wildlife habitats

We investigated several methods for splitting upland from lowland areas in the Muddy Creek watershed. Initially we examined topographic maps at 1:24,000, 1:62,500, 1:100,000 and 1:250,000 scales, each having a different contour interval. Based on this examination, we then constructed upland maps for a series of elevation values from 90 to 120 meters, by 5 meter increments, and compared these to the spatial distribution of land cover classes. We also created maps of slopes greater than 1% and greater than 2%. After comparing these maps we selected the 110 meter contour as the splitting criterion for upland from lowland. Subsequently, this criterion was partially verified in the field. Using this definition of upland, the percentages of the watershed in upland and lowland were 57% and 43%, respectively (Figure 9). As discussed above, we used the upland/lowland map to divide all four water classes and two road classes (light duty and unimproved roads) into separate upland/lowland classes for the past, present, and each future map.

We created the near-water habitats by buffering a 90 meter expansion zone around all features in the open water and 2+ order stream classes (Figure 10). Most of the 21 "buffer" species (B; those species only using habitats near water; Table 2) use both open water and 2+ order streams. Smaller 1st order streams were not included in the water buffer because these features' near-water habitat would be unsuitable for many of the buffer species. A buffer of 90 meters (3 pixels) was used because this distance seemed to be a reasonable compromise between the 11 species using land up to several hundred meters from water (e.g. beaver, *Castor canadensis*) and the 10 species using land 10 - 50 meters from water (e.g. tailed frog, *Ascaphus truei*). This 90 meter buffer was superimposed on each map, including the upland/lowland water and road classes. The resulting maps had a possible 76 land cover classes, 38 inside the water buffer and 38 outside (Table 6), though no map had more than 70 classes present.

We treated the Pre-Settlement map the same as the present and future maps with one exception. As created by ONHP/TNC, the Pre-Settlement map had no hydrographic features. On the present and future maps, transportation features were overlaid on top of the hydrographic network by the University of Oregon team (Mike Flaxman, personal communication 1996). This resulted in road pixels replacing some water pixels, causing some stream habitats to be truncated by roads on the present and future maps. The water buffer, on the other hand, was created from the complete (non-truncated) representation of the open water and 2+ order stream classes. To create water habitat classes for the Pre-Settlement map, we overlaid the complete (non-truncated) present-day hydrographic network, which was also used to create the water buffer classes. Of course, there may be some inaccuracies involved with using present-day hydrography to represent the hydrography of the 1850s. Possible errors could have arisen from removal of beaver ponds, addition of farm ponds, channelization of streams in the lowlands, and modification of channels due to indirect effects of change in land cover, including wetlands. We believe that errors in our model introduced by using the present-day hydrography are preferable to errors from not including any water features on the Pre-Settlement map.

After applying the cross-reference from land cover classes to habitat classes, we tabulated the changing area percentages of habitat classes in the present, possible futures, and past landscapes (Table 7). The most obvious differences in the proportions of habitat classes were between the contemporary landscapes (present and possible futures) and the past landscape. In the contemporary landscapes, conifer classes and grass seed dominated, whereas in the 1850s landscape, older age conifer, mixed forest, savanna, and prairie dominated. We reiterate, however, several reasons for being cautious about these differences and the resulting effect on the biodiversity risk results reported later. The spatial mapping resolution of the 19th century land surveys almost certainly resulted in an under-representation of lowland riparian and marsh habitats. The lack of differentiation of forest age classes in the survey notes precluded use of the finer distinctions that we have in the contemporary data, with the result that all conifer forest in the 1850s landscape was assigned to the oldest age class as the most reasonable alternative. Lastly, some of the fine distinctions in floristic composition recorded by the land surveys were lost in our modeling because we did not have habitat association data for these distinctions.

Risk modeling

The objective of our analysis was to measure changes in biodiversity, represented by species' habitat area, between the present and each of the five future scenarios, and between the present and the past. We regarded habitat area as an index of the abundance of breeding units for each species. Habitat area was determined by the sum of the areas of each habitat assigned to a species in the habitat association matrix (Table 4), without regard to spatial configuration. Change in habitat area for a species in each future scenario was calculated as the ratio of future habitat area to present habitat area, using the present as the baseline for comparison. Change in habitat area for each species in the past was calculated in the same manner, as the ratio of past habitat area to present habitat area, also using the present as the baseline for comparison. By using the present as the baseline for both the future and the past, species' habitat ratios and risks are related, allowing a species' future habitat area (or risk) to be directly compared to its past habitat area (or risk). We calculated the risk to a species for a future (or past) landscape as

$$1 - \frac{\text{future (or past) habitat area}}{\text{present habitat area}} \times 100,$$

obtaining a percentage of habitat area at risk in the future (or past) compared to the present. In this report we express all risks to the nearest whole percent, with a maximum of three significant digits.

We calculated summary risk statistics for taxonomic and other groups of species. Because the skewed empirical distributions of the raw habitat ratios appeared approximately lognormal, we transformed these ratios using natural logarithms. We then computed the mean habitat ratio for the set of species using the transformed habitat ratios, for each landscape. Next, we transformed the mean habitat ratio in the logarithm scale back to the geometric mean on the original scale. The geometric mean of each set of ratios was used as the measure of central tendency for a group of species. We obtained a mean percentage of habitat area at risk from

1 - [geometric mean of habitat ratios] x 100.

Construction of species richness change maps for futures and past

We constructed maps of the Muddy Creek watershed showing changes in species richness (number of species) for each possible future (and the past), compared to the present. For each future or past map, the number of species present in each pixel of habitat for the future (or past) scenario was subtracted from the number of species present in the same pixel in the present. A positive number would indicate a gain in species richness, while a negative number would indicate a loss in species richness, for that pixel of habitat in the future (or past), compared to the present. These species richness change maps aided in the identification of landscape changes that contributed most to changes in species richness in the futures (or past).

RESULTS

Average risk for taxonomic groups of animals

The average risk of habitat loss for a group of species was calculated from individual species' risks (Table 2). The average risk of habitat loss for the 214 native vertebrate species (excluding extirpated species) was highest in the High-Development future (19% - Table 8, Figure 11), with lower risk in the Moderate-Development and Plan-Trend futures (5% and 4%, respectively), and improvement in the Moderate- and High-Conservation futures (4% and 6%, respectively) and the Pre-Settlement past (9%). The number of native species at risk varied for each future scenario (Figure 12): 75% of native species were at risk in the High-Development future, decreasing to 69% in the Moderate-Development future and 56% in the Plan-Trend future, with only 31% at risk in the Moderate-Conservation future, and 40% at risk in the High-Conservation future. A similar proportion (42%) were "at risk" in the past (less habitat in the past than in the present). In summary, the average risk to all 214 native species (Table 8, Figure 11) was lowest in the Moderate- and High- Conservation futures and the number of species at risk (Figure 12) was also smallest in the Moderate- and High-Conservation futures. This overall trend of greater risk with development and less risk with conservation was also reflected in trends within individual species: 39% (83/214) of native species showed a monotonic trend of increasing or level risk with increased development, while only 14% (29/214) showed a monotonic trend of increasing or level risk with increasing conservation.

The trend of higher risk with more development was also present in the averages of risk for the amphibians, the birds, and the mammals (Table 8, Figure 11). The amphibians were the taxonomic group showing both the highest risk (High-Development, 29%) and the highest improvement (High-Conservation, 19%). The reptiles had almost no change in any of the futures (0% - 3%), but showed a dramatic improvement (65% more habitat) in the Pre-Settlement past, compared to the present. The additional reptile habitat in the past was due to the large amount of oak savanna and prairie habitat in the 1850s relative to the present (Figures 2 and 8; Table 7). Oak savanna and prairie habitats (habitats 16 and 17, respectively, on Tables 4 and 6) were used by all but one of the reptiles (11/15 species use both habitats, plus 3 species use one habitat; Table 4), making the reptiles as a group very sensitive to loss of these habitats.

Within each taxonomic group, some species subsets showed the same trends as above, but other subsets were quite divergent (Table 8). Within the amphibians, salamanders and frogs both followed the overall trend of the amphibians, with highest risk in the High-Development future, highest improvement in the High-Conservation future, and some improvement in the Pre-Settlement past. The salamanders had greater risk than the frogs in each possible future.

Within the reptiles (Table 8), the turtles showed the trend of increasing risk with development, but were at risk even in the conservation scenarios. The lizards showed an opposite trend of increasing risk with conservation, and the snakes showed no trend. All three reptile subsets showed improvement in the Pre-Settlement past compared to the present, particularly the lizards and snakes. The differing trends for each reptile subset in the futures accounted for the overall lack of trend within the averaged reptiles.

Within the birds (Table 8), 11/21 subsets showed a trend of risk with development and improvement with conservation. 8/21 bird subsets had this trend monotonically (herons, hawks, shorebirds, owls, woodpeckers, forest insect-eaters, vireos, tanagers/grosbeaks), and 3/21 bird subsets had this trend more weakly (ducks, hummingbirds, warblers). 8/21 bird subsets had little or no trend (grouse, flycatchers, swallows, crows/jays, wrens, thrushes, blackbirds, finches). 2/21 bird subsets showed an opposite trend of risk with conservation and improvement with development (doves/pigeons, sparrows). The bird subsets were highly variable in risk or improvement in the Pre-Settlement past, with some groups showing improvement of at least 75% more habitat in the past than today (owls, hummingbirds, woodpeckers, vireos).

Within the mammals (Table 8), 7/11 subsets showed a monotonic trend of increasing risk with development (shrews/moles, bats, large rodents, squirrels/gophers, bears/raccoons, weasels, cats), with the bats and the squirrels/gophers showing the highest risk. The other subsets showed no consistent trend in the futures (rabbits/hares, voles/mice) or almost no change (coyotes/foxes, deer/elk). Most mammal subsets showed only modest changes in the past: 6/11 subsets had some improvement (more habitat) in the Pre-Settlement past, with the bears/raccoons having the most improvement; 5/11 subsets had risk (less habitat) in the past.

Average risk for other groups of animals

Grouping the species by their status (i.e. extirpated, rare, vulnerable, introduced) also showed that there is a correlation between some groups' status and their magnitude of risk (Table 9, Figure 13, Figure 14). The extirpated (E), rare (R), and vulnerable (V) species showed the common trend of high risk with development and improvement with conservation, with improvement (more habitat) in the Pre-Settlement past compared to the present.

The introduced species (I; Table 9, Figure 13) were (somewhat surprisingly) at risk in all the futures, but they also showed a trend towards more risk in the conservation futures. This trend was consistent with introduced species' preference for human-dominated (developed) landscapes, which was also reflected by the 3 species that (hypothetically) would have had zero habitat (100% risk) in the past (Table 2; Rock Dove, *Columba livia;* House Sparrow, *Passer domesticus;* Norway rat, *Rattus norvegicus*). The other 11 introduced species (hypothetically) would have had 21% more habitat in the past than in the present.

Native habitat specialists (defined here as species using ≤ 10% of the 26 wildlife habitat classes; 14 species) also showed the same trend of risk with development and improvement with conservation (Table 9, Figure 14). Habitat specialists also showed risk (31% less habitat) in the Pre-Settlement past, due in part to the 6 specialists that used only marsh or deciduous riparian habitats, which were both probably under-represented on the Pre-Settlement map due to the coarse resolution of the original survey. Native habitat generalists (defined here as species using ≥ 70% of the 26 wildlife habitat classes; also 14 species) showed very little change in the futures compared to the present, and a small improvement in the Pre-Settlement past.

Individual species at risk of losing ≥ 50% of their habitat

There were 41 high risk species (18% of the 222 native species, including those extirpated) that were at risk of losing ≥ 50% of their habitat in one or more of the possible futures (Table 10). 29% (12/41) of these high risk species were vulnerable species (Oregon or Federal conservation status); by comparison, only 18% (39/222) of the entire native species list were vulnerable species. 7% (3/41) of the high risk species were "rare" (R); by comparison, only 4.5% (10/222) of the entire native species list were "rare". These figures indicate that the high risk species were more likely to be species of concern (vulnerable; rare) than species that were not high risk. 85% (35/41) of the high risk species had ≥ 50% risk in the High-Development future, while only 15% (6/41) had ≥ 50% risk in the Conservation futures. This indicates that the High-Development scenario was a greater threat to habitat loss and resulting loss of biodiversity than the other futures.

To put these numbers into perspective, 27 species (12% of the 222 native species) lost ≥ 50% of their habitat since the Pre-Settlement past (i.e. those species with risk values ≤ -100%; see Table 11 for explanation of risk values for the past). This means that more species (41) could lose ≥ 50% of their habitat in the next 30 years than the number (27) of species that lost ≥ 50% of their habitat in the last 150 years. Only 3 species were on the list of species at risk of losing ≥ 50% of their habitat in the future AND on the list of species that have already lost ≥ 50% of their habitat (Tables 10 and 11): the Burrowing Owl, *Athene cunicularia* (a rare "R" species, also an Oregon Sensitive species and Federal Species of Concern), the Marbled Murrelet, *Brachyramphus marmoratus* (an Oregon Threatened and Federal Threatened species), and the California Condor, *Gymnogyps californianus* (an extirpated "E" species that is essentially extinct, also a Federal Endangered species). This shifting of risk from one set of species to another suggests that the kinds of habitat changes in the past were somewhat different from those envisioned for the futures, for most species. 30% (8/27) of the species that lost ≥ 50% of their habitat since the Pre-Settlement past were vulnerable, compared to only 18% (39/222) of the entire native species list. 19% (5/27) were rare species, compared to only 4.5% (10/222) of the entire native species list. This significant loss of habitat from the past to the present was consistent with, and was probably partly responsible for, these species' designations as species of concern.

Although our analyses did not include population viability, these quantitative indications of possible habitat loss could be considered a first step toward a ranking of species of concern. See Mace and Lande (1991) for ranking criteria based on population persistence.

Changes in species richness in the futures and past

Changes in species richness (number of species) were calculated by comparing habitats in each possible future (or past) to habitats in the present (Figures 15 - 20). There was a trend of largest total area of species loss in the High-Development scenario (Figure 15), decreasing to smallest total area of species loss in the High-Conservation scenario (Figure 19). There was also an opposing trend of smallest total area of species gain in the High-Development scenario (Figure 15), increasing to largest total area of species gain in the High-Conservation scenario (Figure 19). In the Moderate-Conservation future, the total area of species loss was roughly equal to the total area of species gain. In the Pre-Settlement past (Figure 20) areas of changing species richness (gain or loss) dominated the map because of (1) large-scale landscape changes since the 1850s (e.g. increasing human domination and increasing fragmentation of the landscape), and (2) the difference in mapping resolution between the Pre-Settlement and present-day maps. In the Pre-Settlement past (Figure 20), the total area of species gain was greater than the total area of species loss.

DISCUSSION

Methods for predicting potential impacts of human activities on biological diversity across a hierarchy of spatial and temporal scales are needed to make land use planning both clearer and better informed (Hansen et al. 1993, Dale et al. 1994, Freemark 1995). We used an approach for estimating potential risk to biodiversity from past and future land cover associated with landscape changes in the Muddy Creek watershed in the Willamette River Basin in Oregon. Although many of the risks or losses in habitat that we computed by our model were relatively small, it is important to bear in mind that continued change at the same rate has a dramatic compounding effect. For example, a constant rate of habitat loss of 1% per year of the amount remaining results in a 22% loss from present in 25 years and an 87% loss in 200 years.

Although much conservation biology is concerned with individual species of concern, or with threatened species as a group, the strength of our approach is a consideration of a broader definition of biodiversity, in this case all breeding non-fish vertebrates in the Muddy Creek watershed. Correspondingly, our approach produces less certain results as the focus is changed to smaller groups of species or to individual species because of the simplifying assumptions we made in order to compute risks for all species. For example, the Bald Eagle *(Haliaeetus leucocephalus)* may hunt along part of the Muddy Creek, but not on the numerous smaller tributaries in the 2+ order streams class. We modeled the Bald Eagle into all 2+ order streams, which resulted in a probable overestimate of its habitat area. In another example, species that only use old growth forest (e.g. Marbled Murrelet, *Brachyramphus marmoratus;* Vaux's Swift, *Chaetura vauxi*) were modeled into all forests >120 years in age, without consideration of microhabitat features, which probably resulted in an overestimate of these species' habitat areas.

There were other possible sources of error or uncertainty in our analyses. Each set of input data may have been affected by error. The land cover maps provided by the University of Oregon research team may have suffered from errors in assigning land cover classes to pixels. The species-habitat association table (Table 4) may have contained errors as well. Both the land cover maps and the species-habitat association table were affected by the classification system that was used (Table 6). Certain land cover classes were probably better identified than others through the air photo and Thematic Mapper imagery, and certain species were probably better represented than others by the land cover classes that were delineated on the maps. While we did not attempt to model any of these sources of error, some of the error may have been mitigated in the analysis through the calculation of the ratio of habitat area in the future to the same quantity in the present. To the extent that these errors affected the past or future landscapes in a similar way to the present, then error effects may have been partially canceled in the ratio. A further contribution to the robustness of these results was the calculation of averages for change in habitat area across many species, an analysis strategy that may have helped to mitigate errors or weak assumptions for individual species.

Species richness (total number of species) did not change in any of the possible futures, because our definition of species loss was zero pixels of habitat, implying that as long as one pixel of habitat existed, a breeding unit of the species could be supported. Without considering minimum area requirements and intraspecies demographic effects, the loss of a species would require complete elimination of habitat, rather than habitat loss sufficient to reduce populations below sustainable levels. Thus there is a discrepancy between the model results (no loss of species) and reality (8 "E" permanently extirpated species, and 10 "R" rare or locally extirpated species). This discrepancy suggests that: (1) some species may not have enough habitat to sustain a viable population, and/or (2) some of the habitat associations are not accurately reflecting actual habitat use, and/or (3) the extirpations are due to factors other than habitat loss or habitat alteration (e.g. extermination of undesirable species, competition with introduced species, sensitivity to disturbance, pollution). An example of the first explanation is the almost-extinct California Condor *(Gymnogyps californianus)*, which had only 0.5% of the present-day Muddy Creek watershed available as habitat, compared to 114 times more habitat in the Pre-Settlement past (Table 2). If this situation was not sufficient to represent a species loss, the California Condor would surely disappear from the High-Development future, which had only 1/50th of present-day potential Condor habitat.

Model improvements

We want to reiterate some of the simplifying assumptions that we have made in order to analyze a large set of vertebrate species. These include the use of a limited set of habitat classes (Table 6) and a corresponding species-habitat association matrix (Table 4) that only assigned presence or absence in a habitat class. We did not consider area requirements for species, nor the shape or context of a habitat patch, except for proximity to water, and upland versus lowland occurrence of water and roads. Each of these assumptions limited the realism of our analyses. For example, while habitat may serve as a useful indicator of vertebrate demography, the relationship is seldom perfect (Block et al. 1994, Wolff 1995). Many factors may complicate assessments of species-habitat associations, including biotic interactions (e.g. predation and competition), disturbances, chance demographic events, suitability of edge versus interior habitat, and differences in habitat quality and configuration (Freemark et al. 1995). Studies we have in progress indicate, in particular, the need for refinements to the initial model to include habitat quality in the species-habitat association matrix (Barczak et al. in review), and a more restrictive definition of suitable habitat in relation to area sensitivity and interior/edge habitat preferences for at least some forest bird species (Santelmann et al. in preparation). Our model also assumed 100% occupancy of habitat. Many species are relatively rare, even in their most preferred habitat (Robbins et al. 1989, Vickery et al. 1994). Rare species are also those most often at risk of extinction (but see Tilman et al. 1994). For these reasons, it is important to validate species-habitat models to determine if the error level is acceptable (Hansen et al. 1993, Block et al. 1994).

CONCLUSIONS

Although further ecological refinement is still required, modeling approaches such as the one presented here can begin to discriminate the effects of potential landscape change on biodiversity and help inform the decision-making process. We see the assessment based on habitat area in this study as a first step toward a more complete assessment of population viability for a set of species. Population viability is strongly related to area of suitable habitat (Laurance 1991) and to population size (Pimm et al. 1988), which is often a function of habitat area. Augmenting our approach with population viability analysis (PVA) would improve the assessment of risk by incorporating the persistence probability of species within landscapes. Because PVA requires additional life history information and the computation of persistence probability for each species (e.g. Lamberson et al. 1992, Armbruster and Lande 1993, Beier 1993), it is not currently feasible to analyze as large a set of species as in this study. In conducting any PVA, it is also critical to consider the regional context of the study area in relation to the range of the species' populations (Freemark et al. 1993, Ruggiero et al. 1994).

Our approach has been useful for developing and engaging local support for land use planning based on biodiversity considerations. It provides a quantitative ranking of landscape alternatives using a methodology that is relatively simple with few parameters (Doak and Mills 1994) and is adaptable to different definitions of biodiversity. Our approach is sufficiently generic that it can be applied to other spatial and temporal scales and to other regions using data of different levels of resolution. As such, it can facilitate a more comprehensive and hierarchical approach to the development of land use plans for the proactive conservation of biological diversity.

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FIGURE CAPTIONS

Figure 1. Map showing context of Muddy Creek watershed within the Willamette Valley and northwestern Oregon.

Figure 2. Present-day map of the Muddy Creek watershed (from the University of Oregon research team). Habitats in Figures 2 - 8 are shaded, from lightest to darkest: lightest (row crops, grass seed/grain, pasture, prairie, vineyards, shrub/brush); lighter (x-mas trees, hybrid poplar, orchards, oak savanna); medium (Douglas-fir forest 0-40 yrs, Douglas-fir forest 40-120 yrs, mixed forest, oak/hardwood forest); darker (Douglas-fir forest >120 yrs, lowland deciduous riparian); darkest (lowland herbaceous marsh, all streams, open water, hedgerows, urban-residential, herbaceous roadsides).

Figure 3. Possible future map of the Muddy Creek watershed for the year 2025: High-Development scenario (from the University of Oregon research team). This scenario features the highest human population increase, and the most intensive use of forest and agricultural resources. See Figure 2 caption for information on shading of habitat classes.

Figure 4. Possible future map of the Muddy Creek watershed for the year 2025: Moderate-Development scenario (from the University of Oregon research team). This scenario features human population increase and resource use midway between the High-Development and Plan-Trend scenarios. See Figure 2 caption for information on shading of habitat classes.

Figure 5. Possible future map of the Muddy Creek watershed for the year 2025: Plan-Trend scenario (from the University of Oregon research team). This scenario features human population increase and resource use at levels projected from current trends. See Figure 2 caption for information on shading of habitat classes.

Figure 6. Possible future map of the Muddy Creek watershed for the year 2025: Moderate-Conservation scenario (from the University of Oregon research team). This scenario features human population increase and resource use midway between the Plan-Trend and High-Conservation scenarios. See Figure 2 caption for information on shading of habitat classes.

Figure 7. Possible future map of the Muddy Creek watershed for the year 2025: High-Conservation scenario (from the University of Oregon research team). This scenario features a small human population increase, and the most conservative use of forest and agricultural resources. See Figure 2 caption for information on shading of habitat classes.

Figure 8. Pre-Settlement (1850s) map of the Muddy Creek watershed (from Oregon Natural Heritage Program and The Nature Conservancy, John Christy, personal communication 1996). The present-day hydrologic network was overlaid on the map of Pre-Settlement vegetation classes. See Figure 2 caption for information on shading of habitat classes.

Figure 9. Map showing areas defined as upland (dominated by Douglas-fir forests) and lowland (dominated by agricultural lands), based on the 110 m contour in elevation.

Figure 10. Map showing areas defined as near-water, i.e. lying within a 90 m buffer of open water or 2+ order streams.

Figure 11. Risk to habitat area, compared to the present, for taxonomic groups of native species, excluding introduced (I) and extirpated (E) species. Risk is represented by geometric mean proportion at risk, given in percents (rounded to the nearest whole percent). Values > 0% indicate habitat loss (risk) compared to the present; values < 0% indicate habitat gain (improvement) compared to the present. See Table 8 for a tabular summary of the risk to taxonomic groups.

Figure 12. Percent of individual species at risk of losing habitat (risk value > 0% in Table 2) in each possible future and in the Pre-Settlement past, for the 214 native (excluding extirpated) species. Above the 50% value (dotted line), the number of species at risk of losing habitat is greater than the number of species gaining habitat; below the 50% value (dotted line), the number of species at risk of losing habitat is less than the number of species gaining habitat. The Moderate-Conservation future has the lowest number of species at risk.

Figure 13. Risk to habitat area, compared to the present, within other groups of species: introduced species (I); extirpated species (E); rare species (R); vulnerable species (V). Risk is represented by geometric mean proportion at risk, given in percents (rounded to the nearest whole percent). Values > 0% indicate habitat loss (risk) compared to the present; values < 0% indicate habitat gain (improvement) compared to the present. See Table 9 for a tabular summary of the risk to these groups.

Figure 14. Risk to habitat area, compared to the present, within habitat specialists and generalists, which are defined here as those species using ≤ 10% and ≥ 70%, respectively, of wildlife habitat classes in Table 6 (excludes E-extirpated and I-introduced species). Risk is represented by geometric mean proportion at risk, given in percents (rounded to the nearest whole percent). Values > 0% indicate habitat loss (risk) compared to the present; values < 0% indicate habitat gain (improvement) compared to the present. See Table 9 for a tabular summary of the risk to these groups.

Figure 15. Map of changes in species richness (number of species) for habitats in the High-Development scenario, compared to the present day. The total area of decreasing species richness or loss of biodiversity (darker) is larger than the total area of increasing species richness (lighter).

Figure 16. Map of changes in species richness (number of species) for habitats in the Moderate-Development scenario, compared to the present day. The total area of decreasing species richness or loss of biodiversity (darker) is larger than the total area of increasing species richness (lighter).

Figure 17. Map of changes in species richness (number of species) for habitats in the Plan-Trend scenario, compared to the present day. The total area of decreasing species richness or loss of biodiversity (darker) is larger than the total area of increasing species richness (lighter).

Figure 18. Map of changes in species richness (number of species) for habitats in the Moderate-Conservation scenario, compared to the present day. The total area of decreasing species richness or loss of biodiversity (darker) is roughly equal to the total area of increasing species richness (lighter).

Figure 19. Map of changes in species richness (number of species) for habitats in the High-Conservation scenario, compared to the present day. The total area of decreasing species richness or loss of biodiversity (darker) is smaller than the total area of increasing species richness (lighter).

Figure 20. Map of changes in species richness (number of species) for habitats in the Pre-Settlement past, compared to the present day. The total area of decreasing species richness or loss of biodiversity (darker) is smaller than the total area of increasing species richness (lighter). Areas of changing species richness are widespread because of (1) large-scale landscape changes since the 1850s, and (2) the change in mapping resolution between Pre-Settlement and present-day maps.

Location of Muddy Creek Watershed

with EMAP hexagons

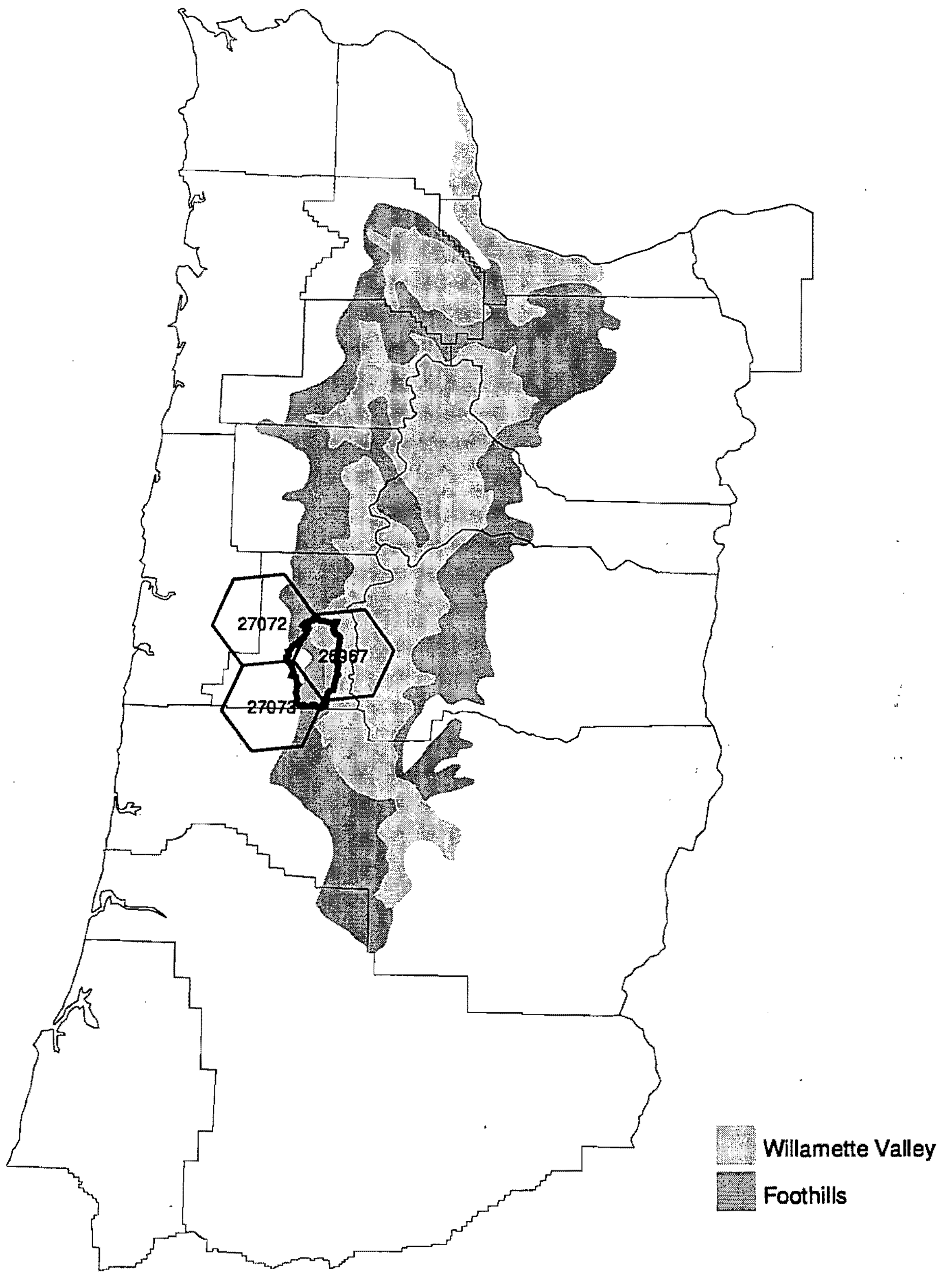

Figure 1

Present Landscape

from U of Oregon ISE, ODFW, OSU/USFS CLAMS

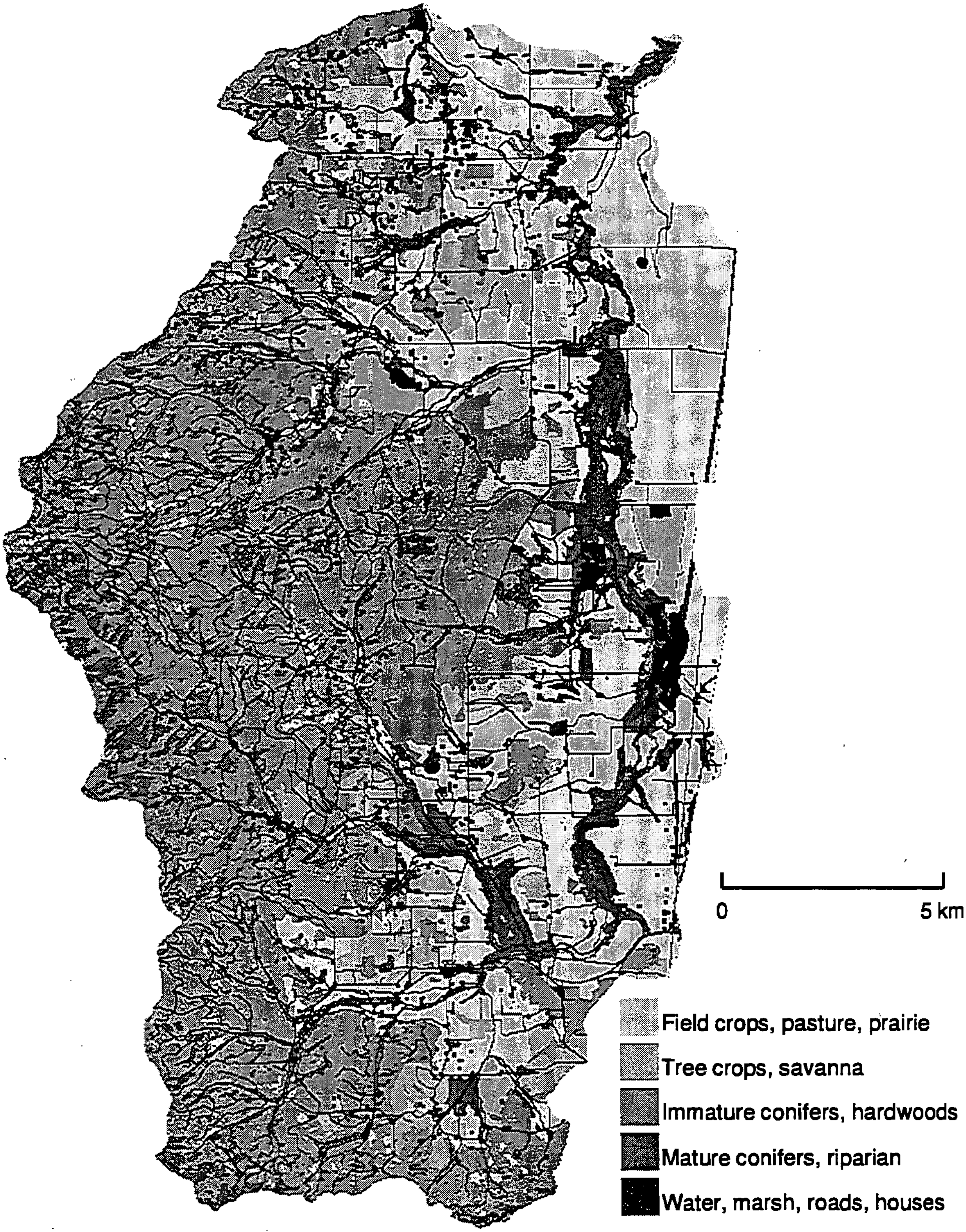

Figure 2

High Development Future

from U of Oregon ISE

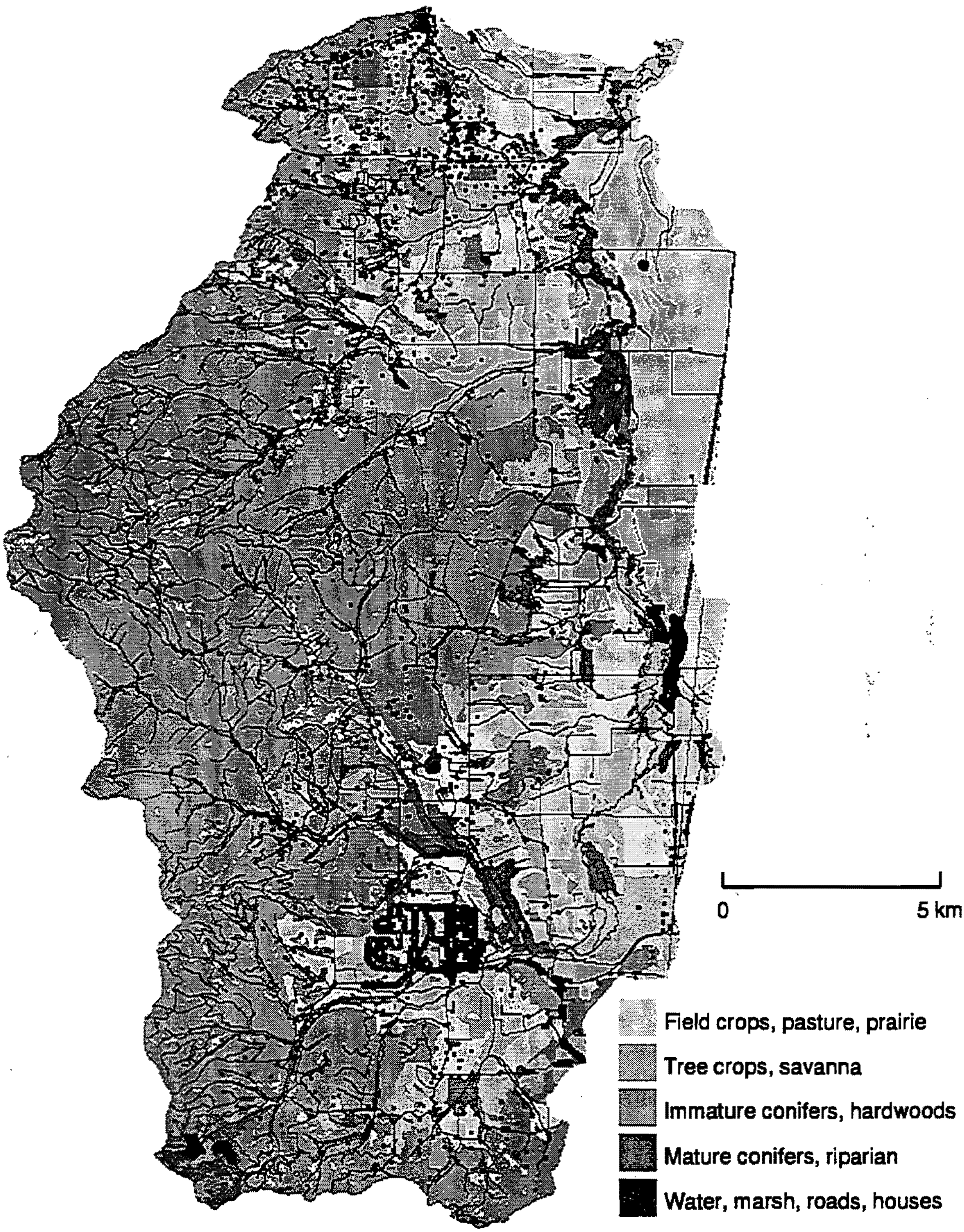

Figure 3

Moderate Development Future

from U of Oregon ISE

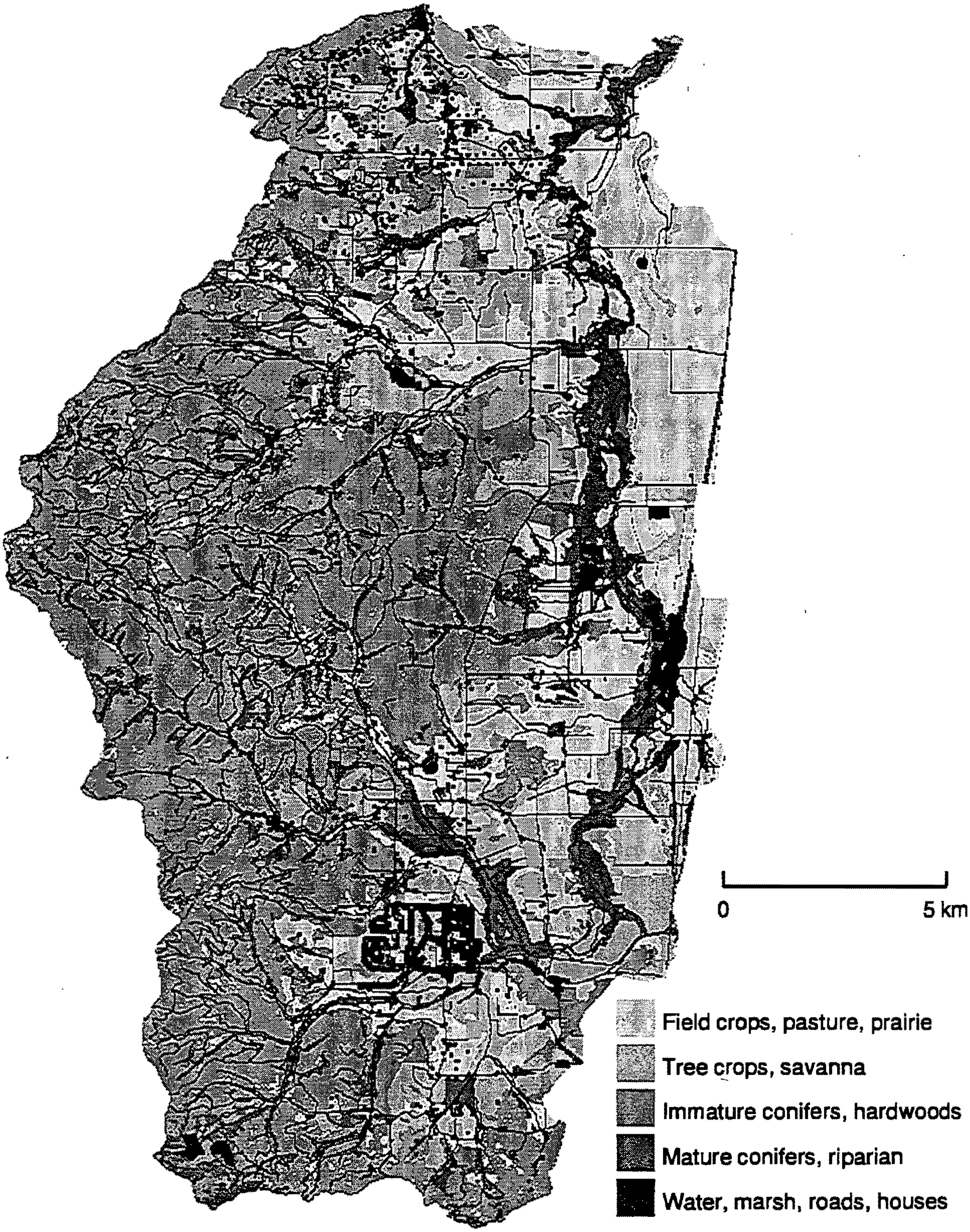

Figure 4

Plan-trend Future
from U of Oregon ISE

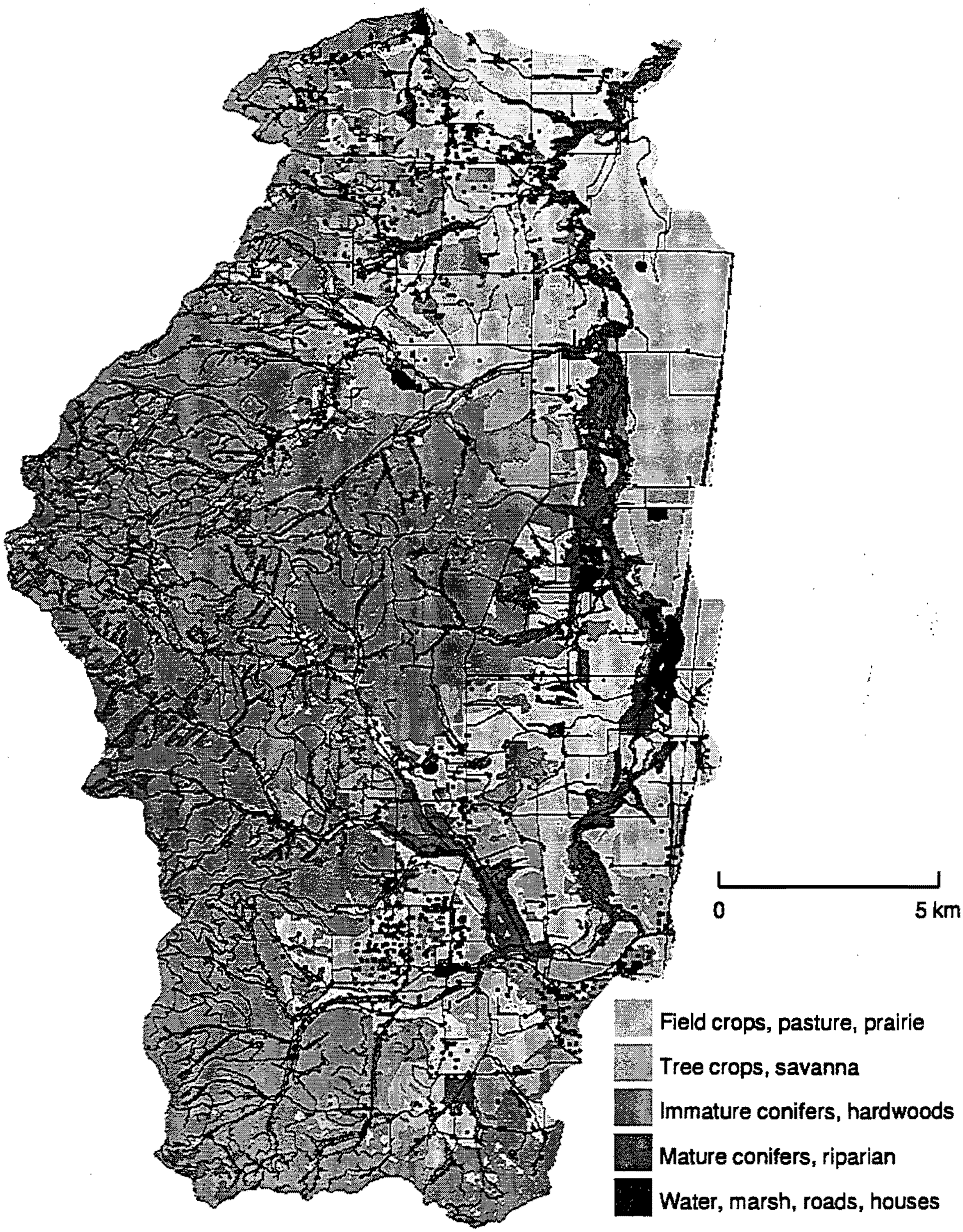

Figure 5

Moderate Conservation Future

from U of Oregon ISE

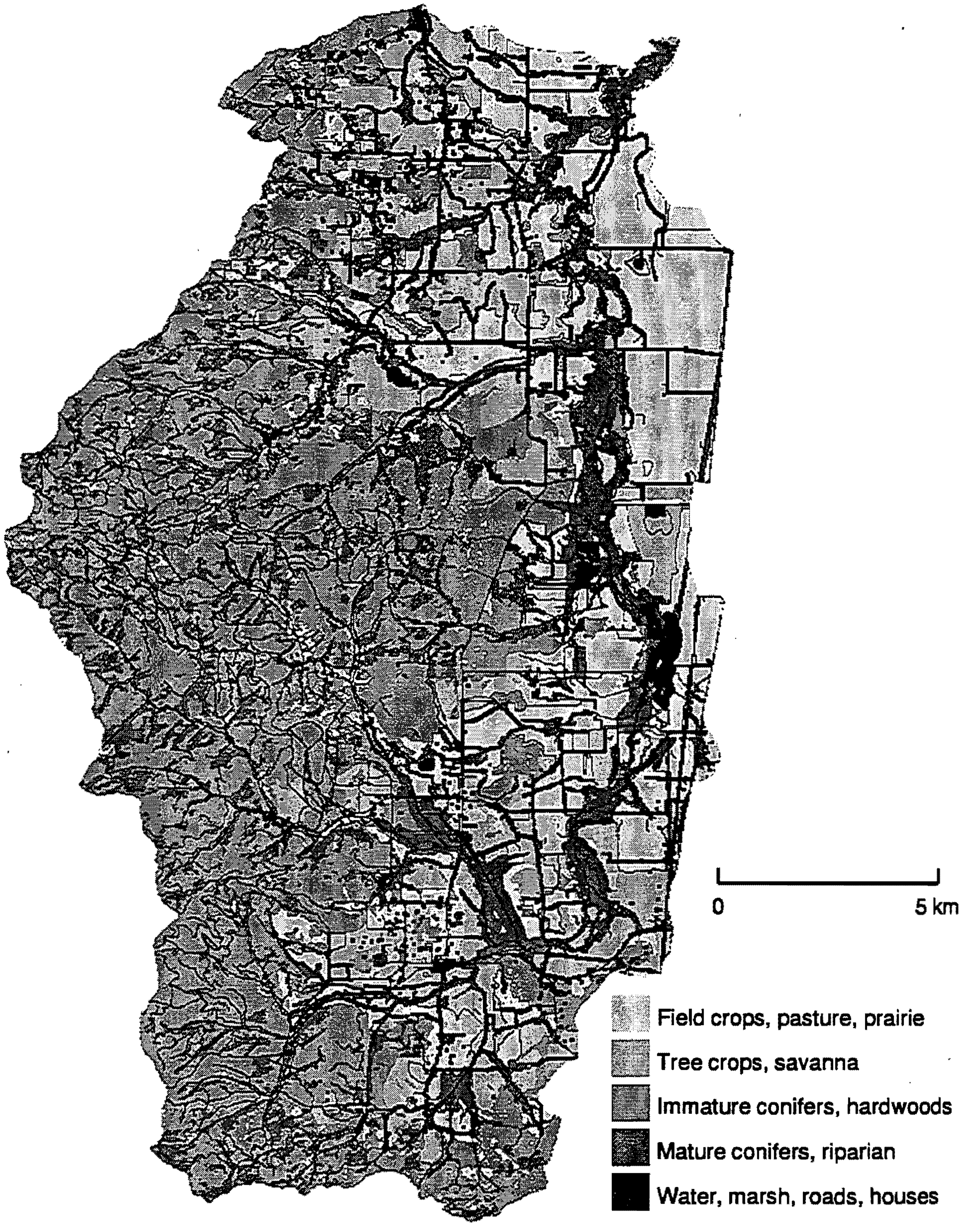

Figure 6

High Conservation Future
from U of Oregon ISE

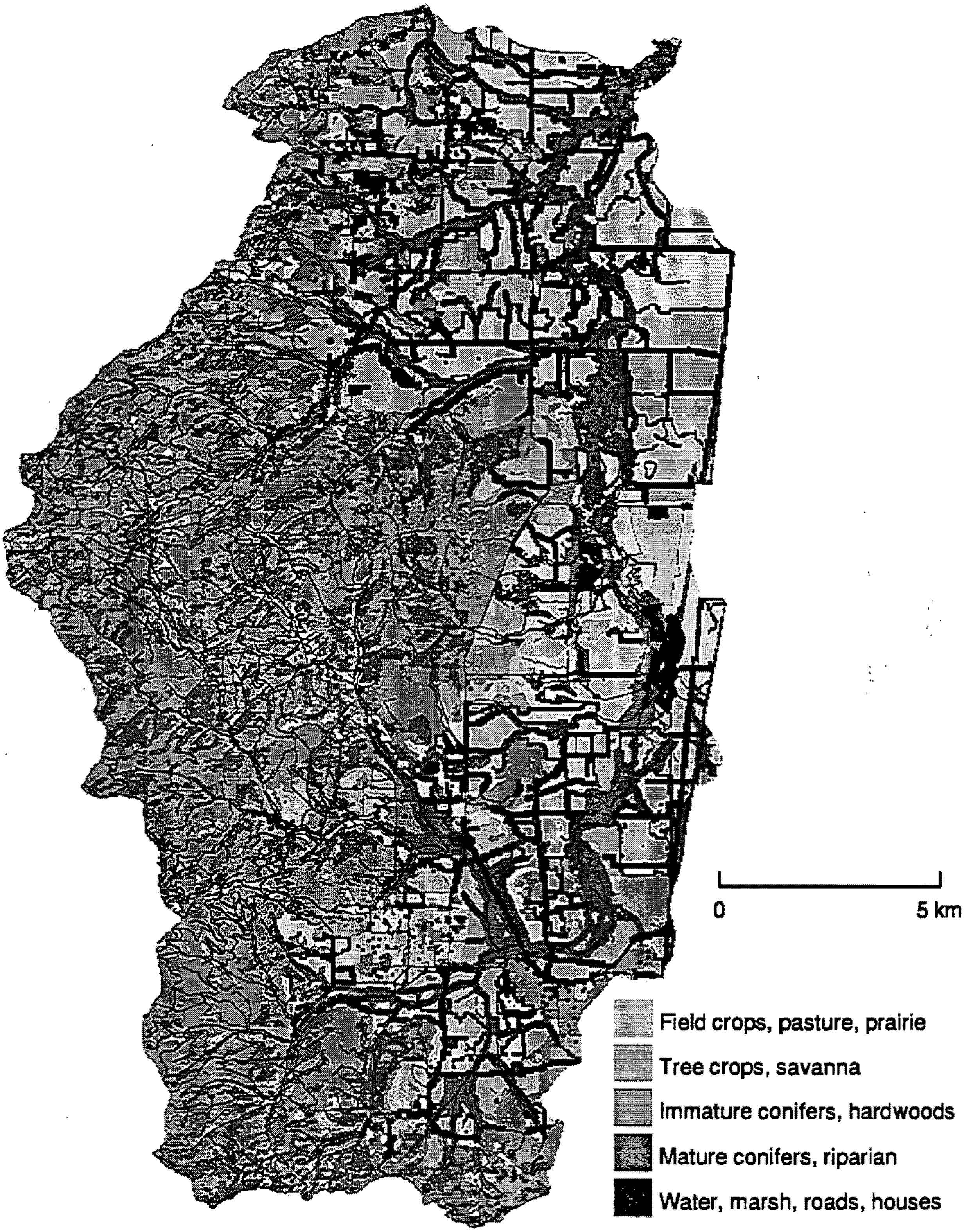

Figure 7

1850s Landscape
from Oregon Natural Heritage Program

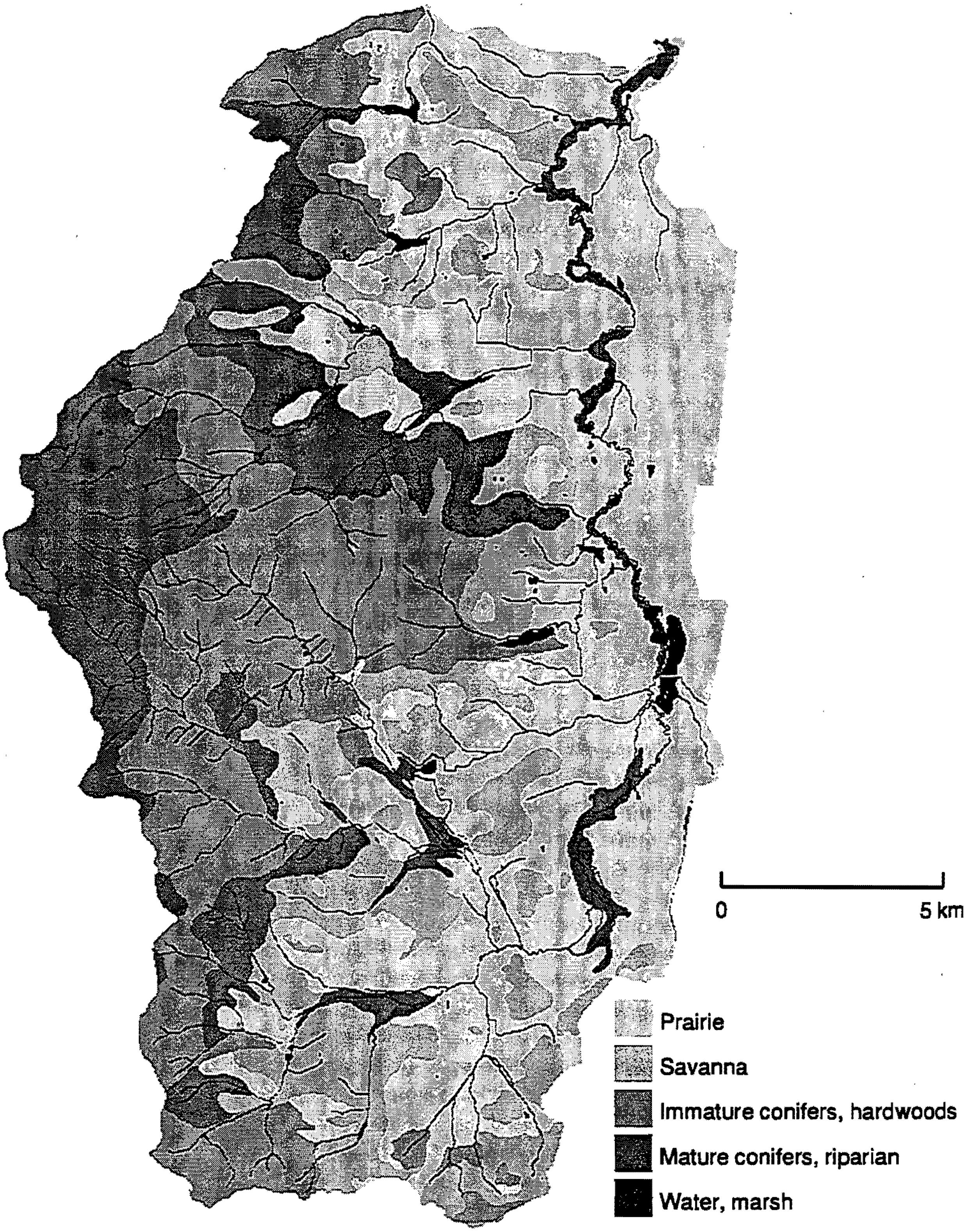

Figure 8

Upland and Lowland of Muddy Creek Watershed

Based on 110 meter Contour

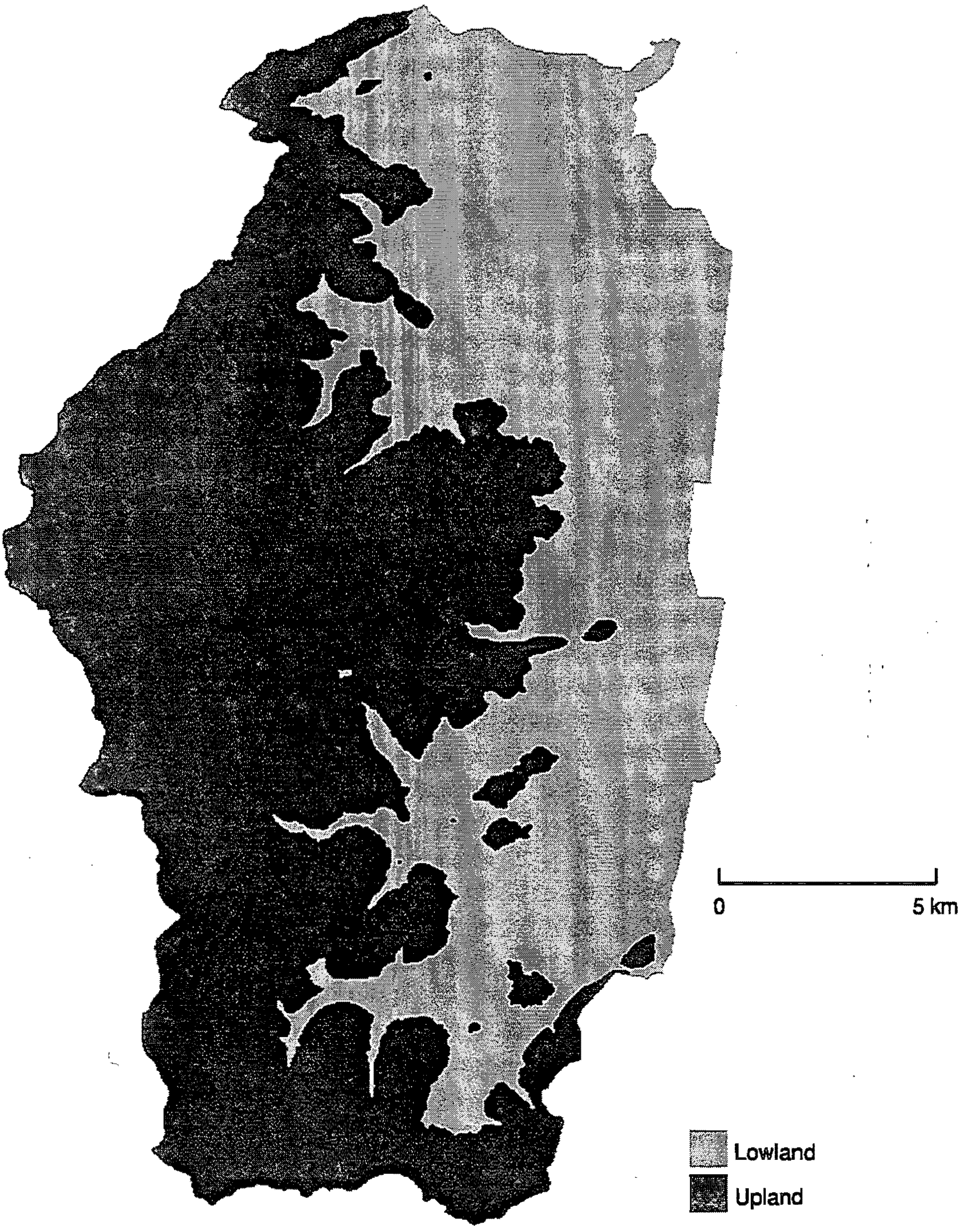

Figure 9

Water Habitats of Muddy Creek Watershed

Based on 90 meter Buffer of 2+ Order Streams and Open Water

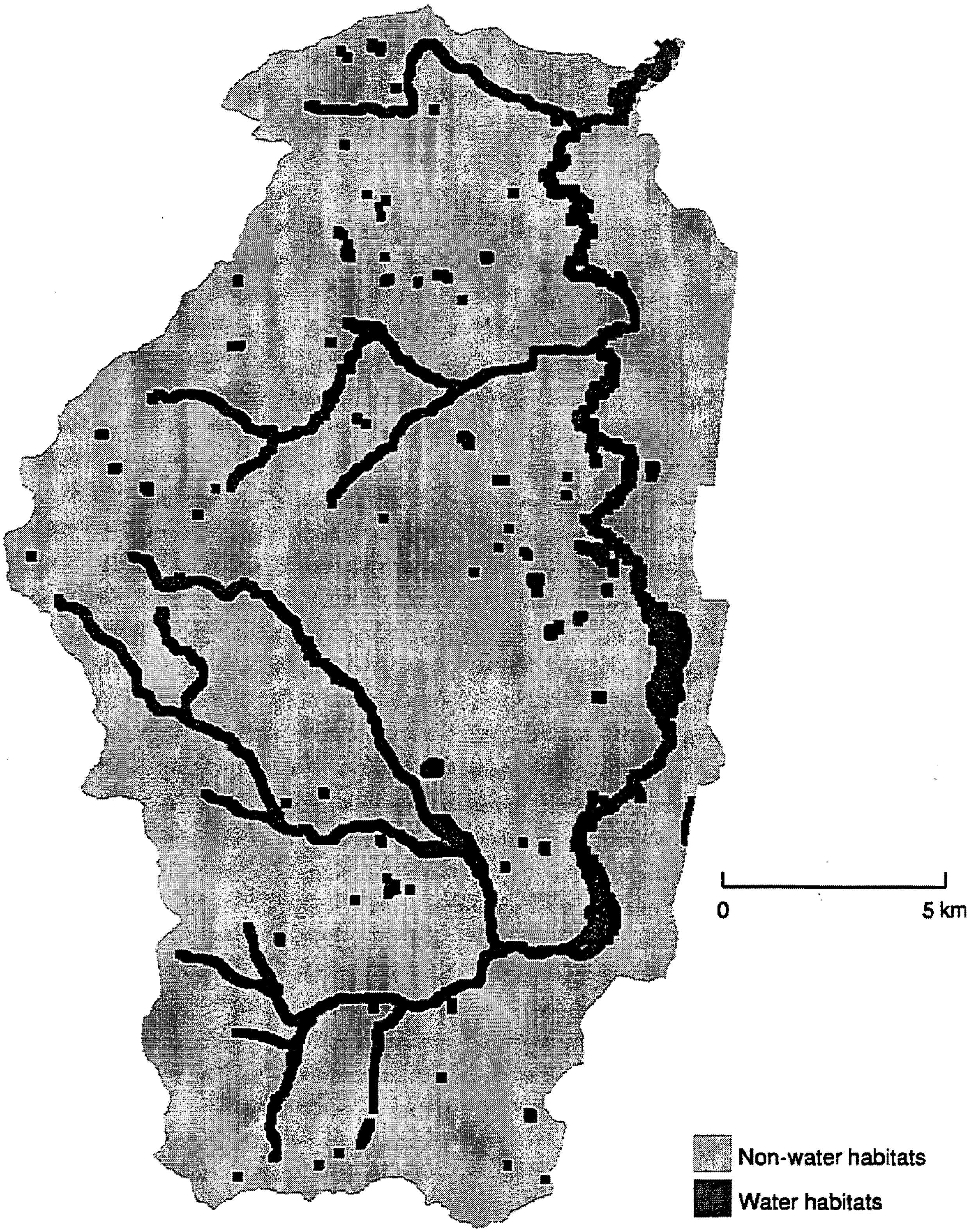

Figure 10

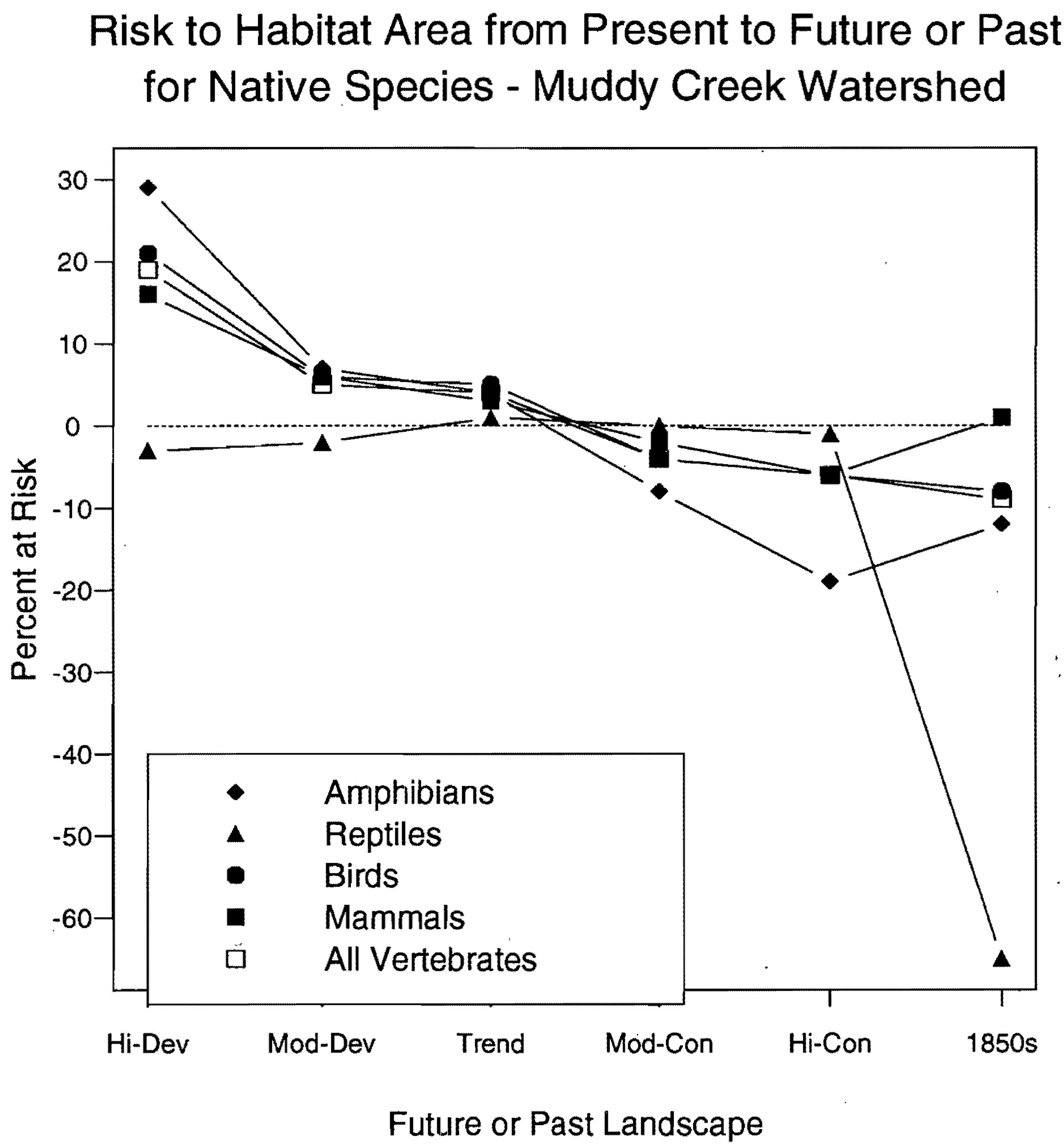
Risk to Habitat Area from Present to Future or Past
for Native Species - Muddy Creek Watershed
30
20
10
0
-10
-20
-30
-40
-50
-60
Percent at Risk
Amphibians
Reptiles
Birds
Mammals
All Vertebrates
Hi-Dev
Mod-Dev
Trend
Mod-Con
Hi-Con
1850s
Future or Past Landscape

Figure 11

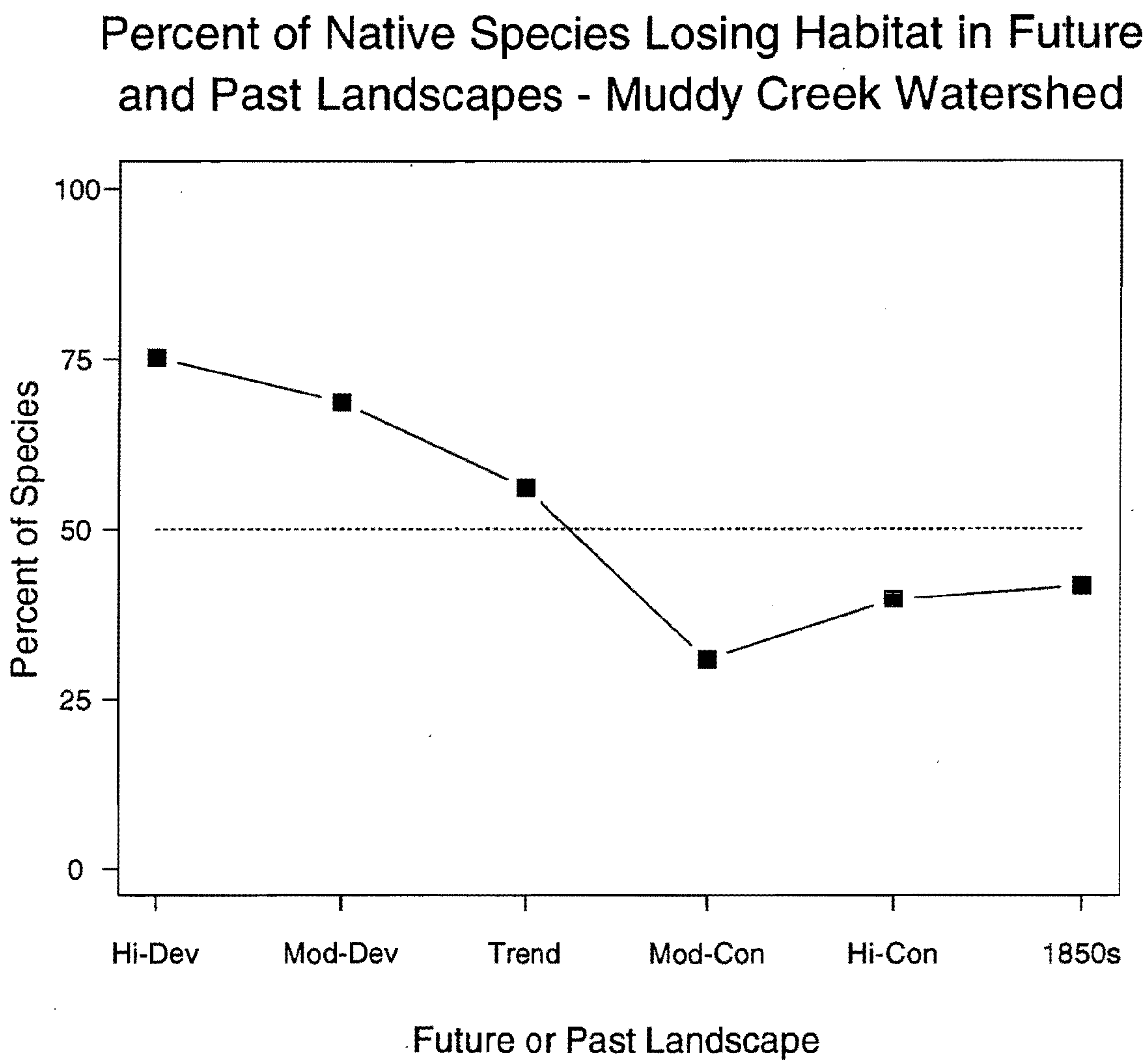
Percent of Native Species Losing Habitat in Future and Past Landscapes - Muddy Creek Watershed
100
75
50
25
0
Percent of Species
Hi-Dev
Mod-Dev
Trend
Mod-Con
Hi-Con
1850s
Future or Past Landscape

Figure 12

Risk to Habitat Area from Present to Future or Past for Selected Species Subsets - Muddy Creek Watershed

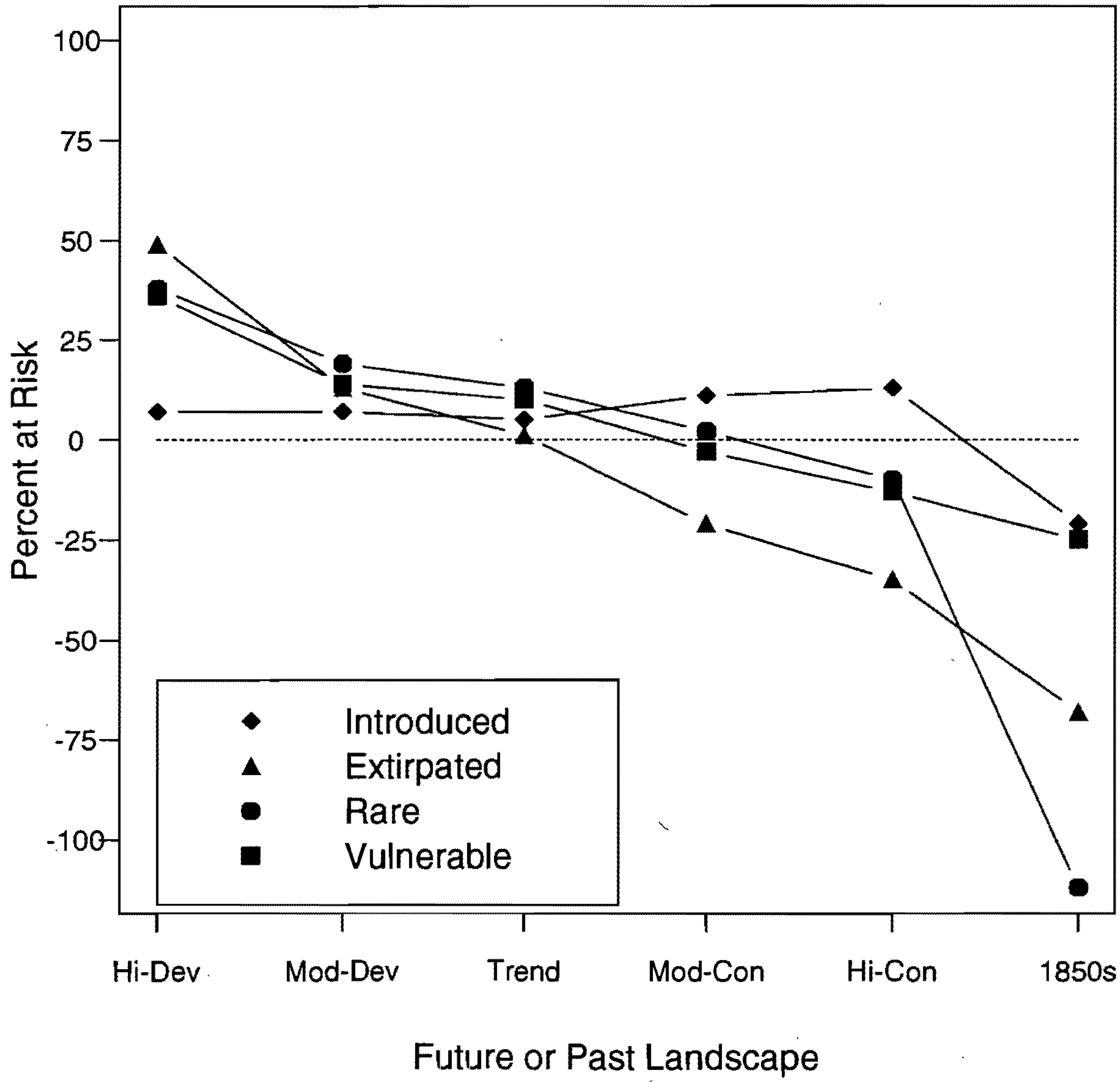

Figure 13

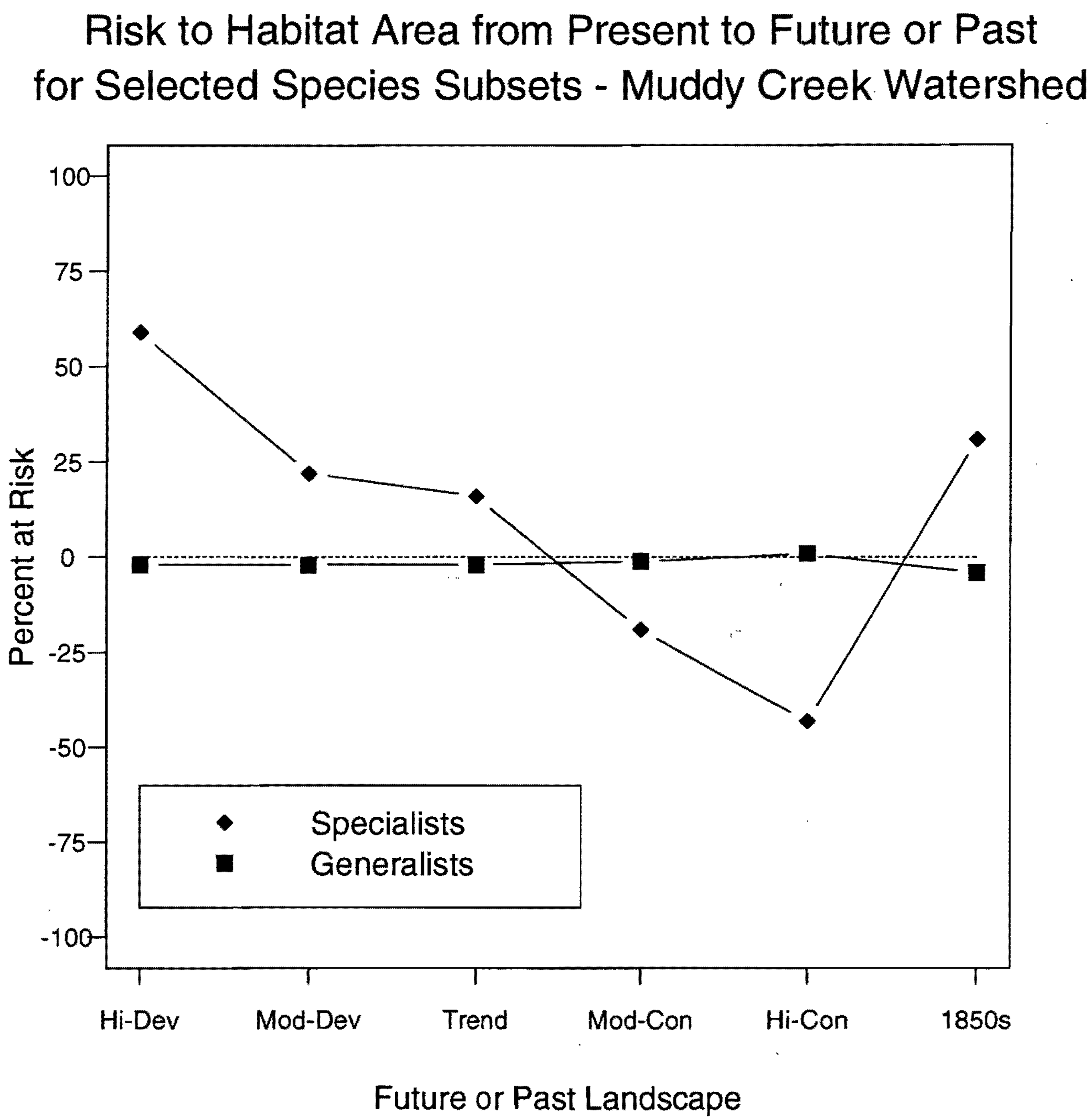
Risk to Habitat Area from Present to Future or Past
for Selected Species Subsets - Muddy Creek Watershed
100
75
50
25
0
-25
-50
-75
-100
Percent at Risk
Specialists
Generalists
Hi-Dev
Mod-Dev
Trend
Mod-Con
Hi-Con
1850s
Future or Past Landscape

Figure 14

Change in Native Species Richness from Present to High Development Future

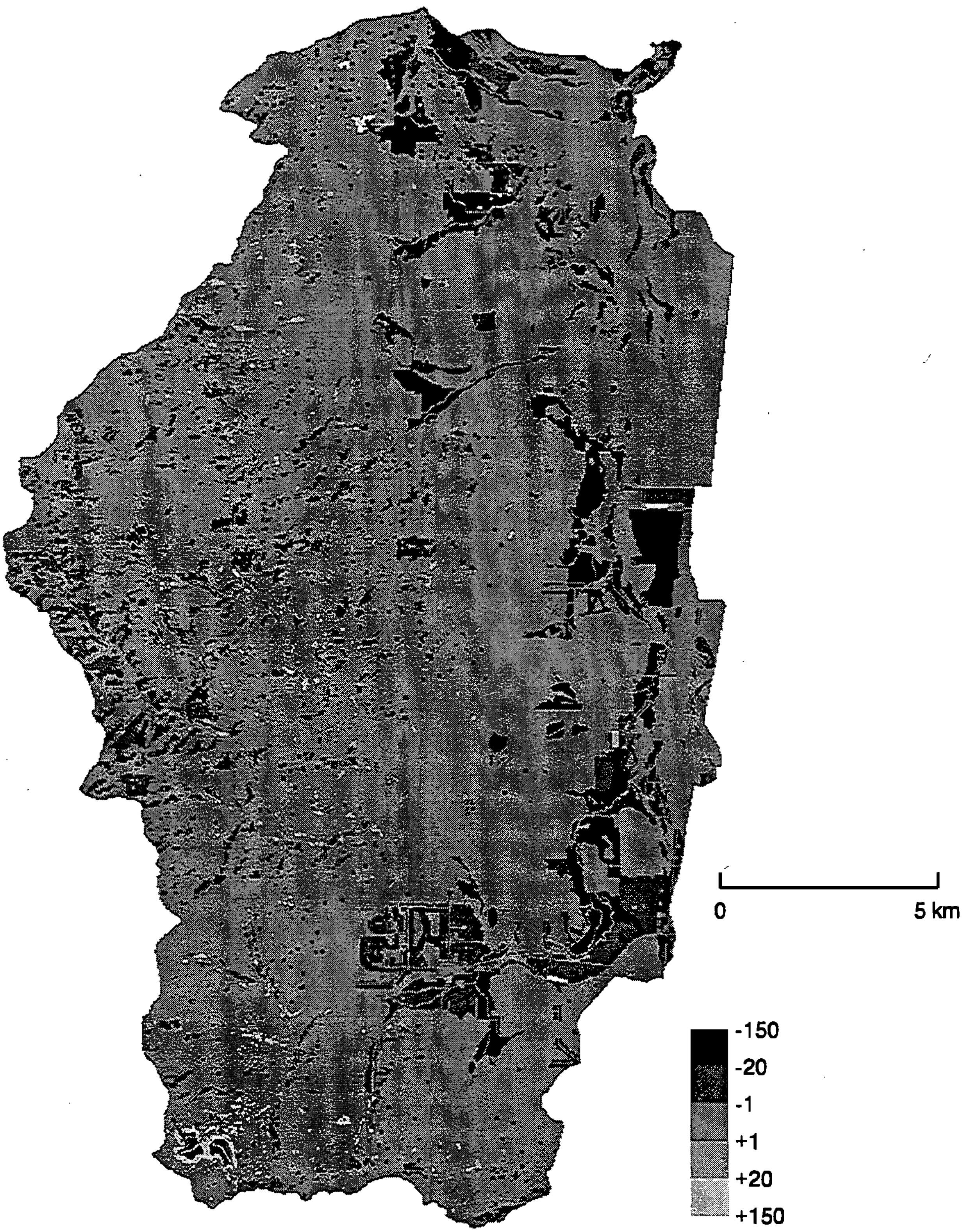

Figure 15

Change in Native Species Richness from Present to Mod Development Future

Figure 16

Change in Native Species Richness from Present to Plan-Trend Future

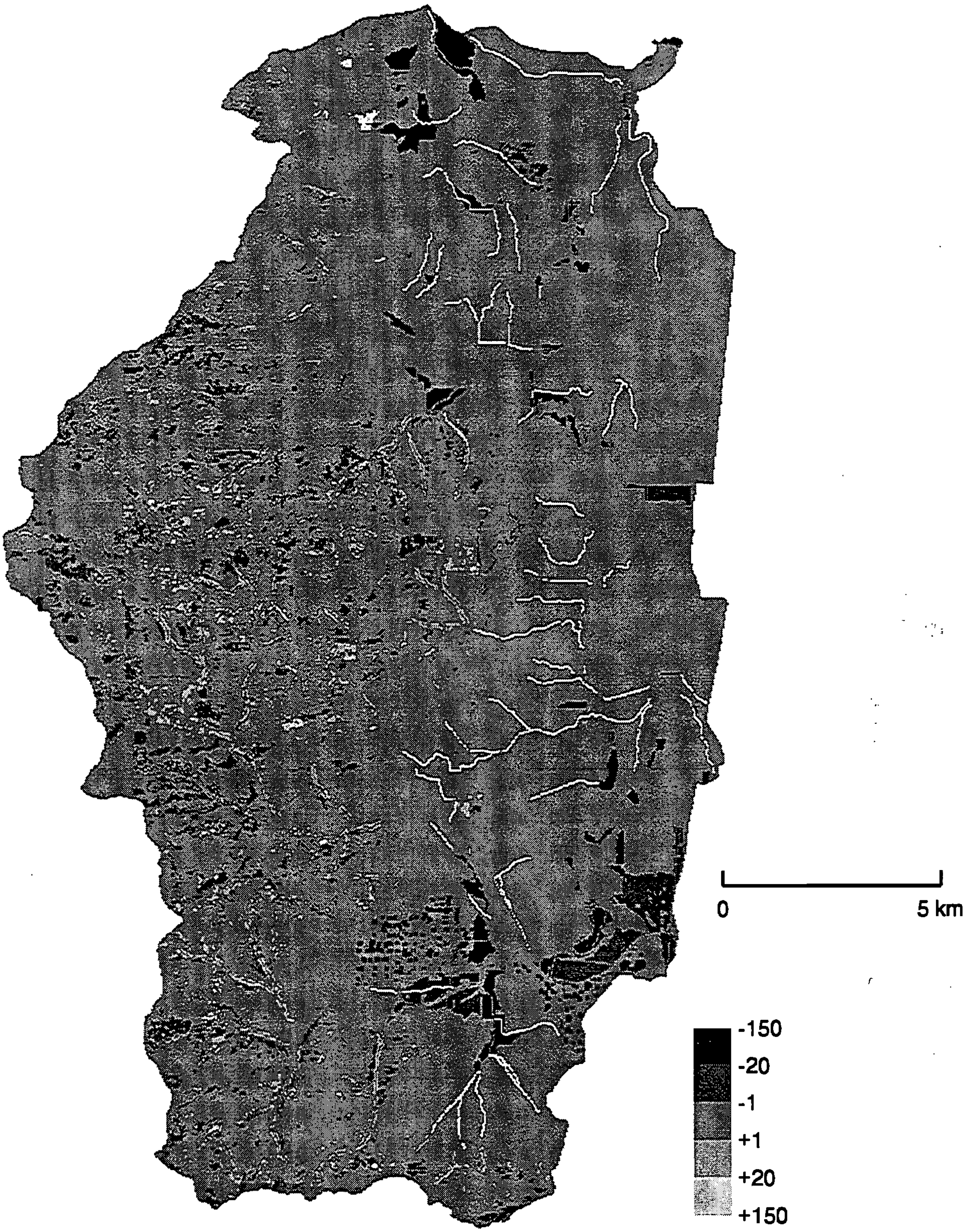

Figure 17

Change in Native Species Richness from Present to Mod Conservation Future

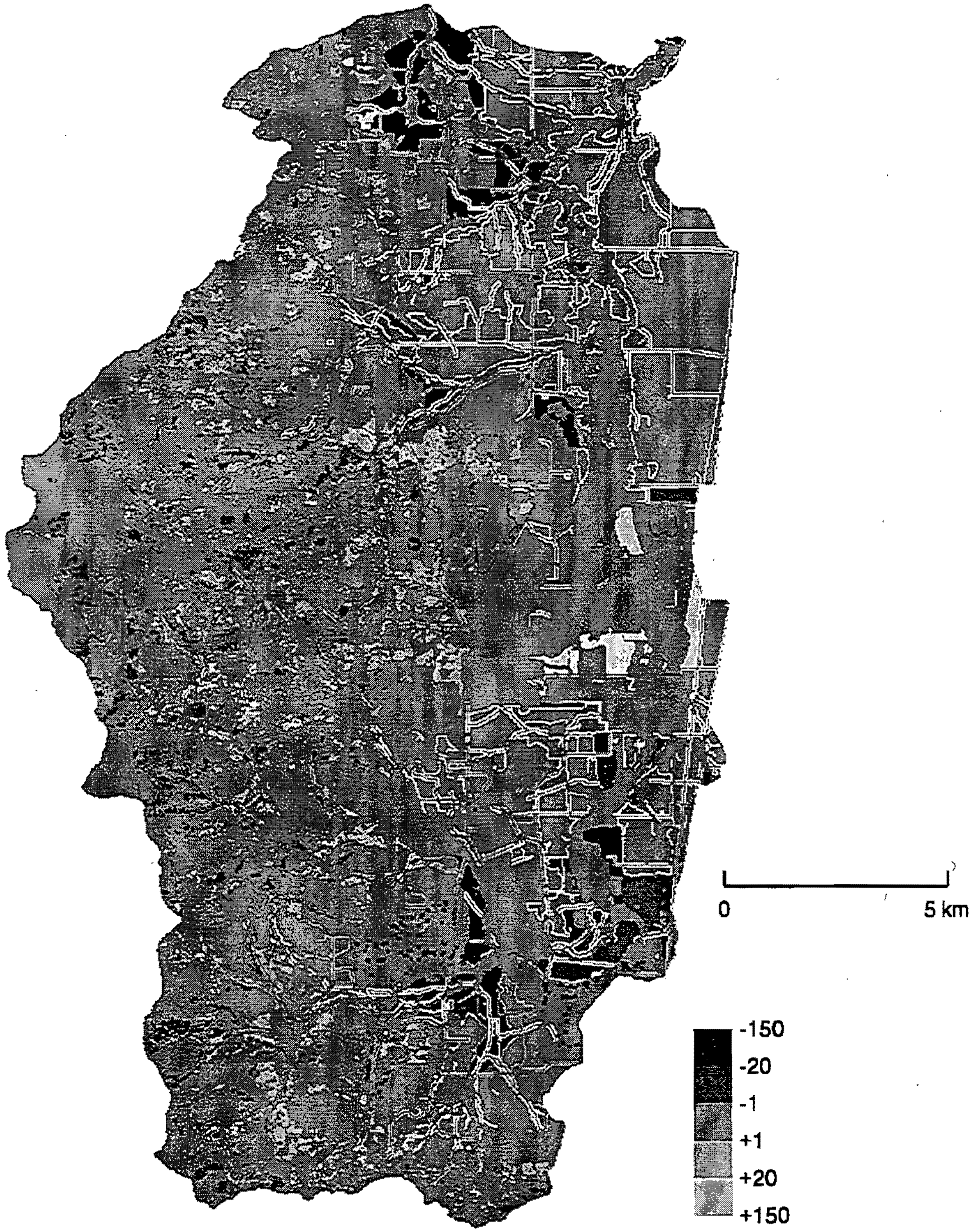

Figure 18

Change in Native Species Richness from Present to High Conservation Future

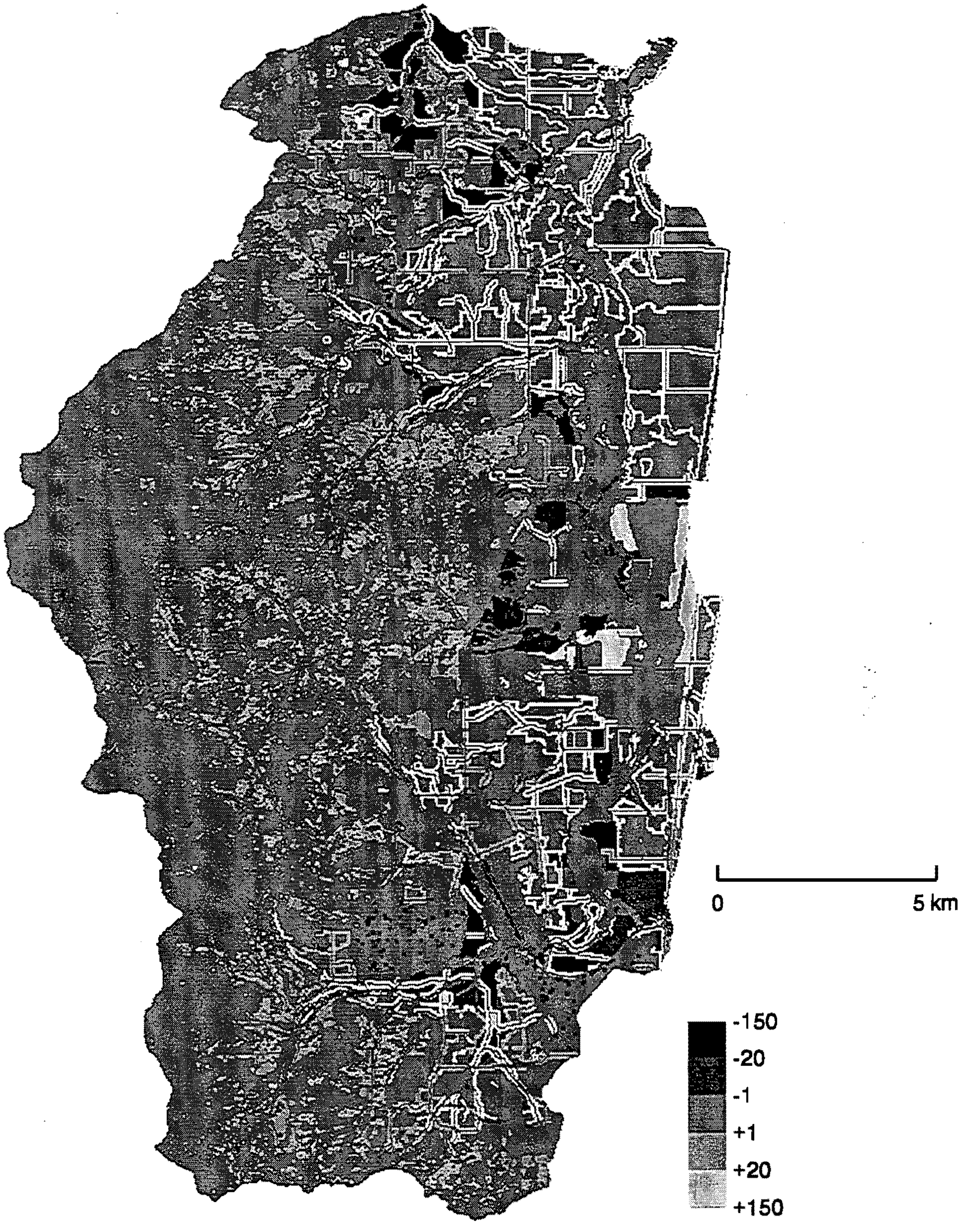

Figure 19

Change in Native Species Richness from Present to 1850s Survey

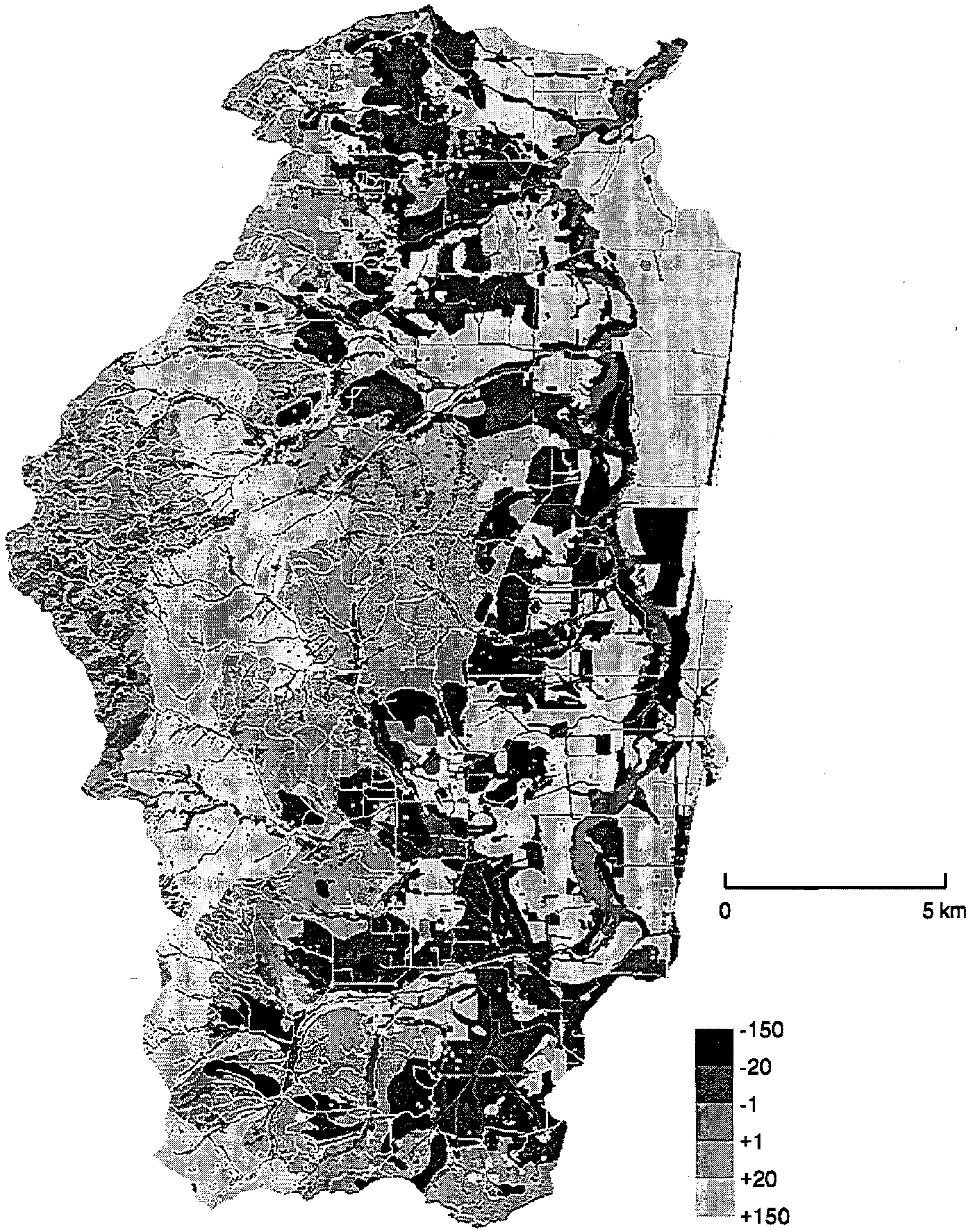

Figure 20

Table 1. Summary data for the 236 breeding vertebrates (excluding fish and humans) in the Muddy Creek watershed. Codes in table columns are: I (introduced, non-native species); E (species permanently extirpated from the Muddy Creek watershed after European settlement in the 1800s); R (rare, uncommon, or locally extirpated species; may breed successfully in the future with habitat improvement); V (vulnerable species with Oregon or Federal threatened, endangered, or other conservation status; see Table 2 for details); B (species that use buffer habitat near water).

	Total Species	Native (all but I)	I Introduced	E Extirpated	R Rare	V Vulnerable	B Buffer
Amphibians	14	13	1	1	0	5	4
Reptiles	16	15	1	0	0	3	3
Birds	135	129	6	3	8	16	10
Mammals	71	65	6	4	2	15	4
Totals	236	222	14	8	10	39	21

Table 2. Data for the 236 breeding vertebrates (excluding fish and humans) in the Muddy Creek watershed. See Table 1 caption for explanation of codes (I, E, R, B). Additional codes relate to vulnerable (V in other tables) species with Oregon or Federal conservation status (O-S = Oregon Sensitive; O-T = Oregon Threatened; O-E = Oregon Endangered; F-S = Federal Species of Concern; F-C = Federal Candidate; F-T = Federal Threatened; F-E = Federal Endangered). For future and past scenarios, values are given as risk of habitat loss, where risk =1 - [future (or past) habitat area/present habitat area]), given in percents (nearest whole percent; ≤ three significant digits). Values > 0% indicate habitat loss (risk) compared to the present; values < 0% indicate habitat gain (improvement) compared to the present. Future and past scenarios are: Hi-D - High Development; Mod-D = Moderate Development; Trend = Plan-Trend; Mod-C = Moderate Conservation; Hi-C = High Conservation; 1850s = Pre-Settlement vegetation reconstructed from 1850s survey. % habitats = percent of 26 wildlife habitat classes (Table 6) that the species uses. % area = percent area of the present-day Muddy Creek watershed (32,300 ha) that the species uses.

AMPHIBIANS

Common Name	Scientific Name	Codes	Hi-D	Mod-D	Trend	Mod-C	Hi-C	1850s	% habitats	% area
northwestern salamander	*Ambystoma gracile*		59	34	30	-2	-41	-33	23	29
long-toed salamander	*Ambystoma macrodactylum*		-1	0	-1	-2	-3	-16	81	85
clouded salamander	*Aneides ferreus*	O-S	81	47	34	-9	-64	24	8	21
ensatina	*Ensatina eschscholtzii*		3	1	-1	-1	0	-20	23	44
Dunn's salamander	*Plethodon dunni*		39	-11	-9	-29	-54	-69	12	2
western redback salamander	*Plethodon vehiculum*		1	0	-2	-2	1	29	23	43
roughskin newt	*Taricha granulosa*		11	5	2	2	2	-51	69	66
Pacific giant salamander	*Dicamptodon tenebrosus*	B	17	-4	-4	-13	-23	-30	19	4
s. torrent salamander	*Rhyacotriton variegatus*	B, O-S, F-S	1	1	0	0	0	-2	4	2
tailed frog	*Ascaphus truei*	B, O-S, F-S	31	-9	-8	-24	-43	-56	15	2
Pacific chorus frog	*Pseudacris regilla*		0	0	-1	0	0	-7	96	93
red-legged frog	*Rana aurora*	B, O-S, F-S	31	-1	0	-23	-33	29	42	11
bullfrog	*Rana catesbeiana*	I	15	0	0	-16	-22	9	12	2
spotted frog	*Rana pretiosa*	E, O-S, F-C	15	0	0	-16	-22	9	12	2

REPTILES

Common Name	Scientific Name	Codes	Hi-D	Mod-D	Trend	Mod-C	Hi-C	1850s	% habitats	% area
painted turtle	*Chrysemys picta*	B, O-S	27	17	15	12	11	39	15	3
western pond turtle	*Clemmys marmorata*	B, O-S, F-S	27	17	15	11	6	-128	23	3
slider	*Trachemys scripta*	B, I	27	17	15	12	11	39	15	3
northern alligator lizard	*Elgaria coerulea*		-60	-36	-27	-6	21	-44	27	26
southern alligator lizard	*Elgaria multicarinata*		22	19	23	11	-21	-335	35	18

Common Name	Scientific Name	Codes	Hi-D	Mod-D	Trend	Mod-C	Hi-C	1850s	% habitats	% area
western fence lizard	*Sceloporus occidentalis*		-36	-18	-14	6	26	-119	42	35
western skink	*Eumeces skiltonianus*		-4	-3	-2	-7	-10	-32	65	72
rubber boa	*Charina bottae*		-56	-33	-25	-7	17	-175	35	28
racer	*Coluber constrictor*		-4	2	4	9	5	-64	42	39
sharptail snake	*Contia tenuis*	O-S	-8	-4	-2	-4	-7	-42	62	65
ringneck snake	*Diadophis punctatus*		-4	-3	-2	-7	-10	-32	65	72
gopher snake	*Pituophis melanoleucus*		-9	-7	2	-8	-19	-121	54	36
w. terrestrial garter snake	*Thamnophis elegans*		-3	-1	1	1	-1	6	58	46
northwestern garter snake	*Thamnophis ordinoides*		-3	-3	-2	-7	-10	-31	77	74
common garter snake	*Thamnophis sirtalis*		-3	-3	-2	-7	-10	-31	77	74
western rattlesnake	*Crotalus viridis*		29	6	10	-7	-22	-132	15	12

BREEDING BIRDS

Common Name	Scientific Name	Codes	Hi-D	Mod-D	Trend	Mod-C	Hi-C	1850s	% habitats	% area
Pied-billed Grebe	*Podilymbus podiceps*		18	-11	0	-30	-42	16	12	1
American Bittern	*Botaurus lentiginosus*		50	1	1	-52	-73	70	4	<1
Great Blue Heron	*Ardea herodias*	B	28	3	-4	-14	-20	31	54	14
Green Heron	*Butorides virescens*	B	31	-1	-1	-24	-34	28	38	11
Black-crowned Night-Heron	*Nycticorax nycticorax*	E	39	3	0	-29	-38	57	12	8
Canada Goose	*Branta canadensis*	B	18	12	12	18	24	-23	38	5
Wood Duck	*Aix sponsa*	B	29	1	2	-21	-29	33	31	10
Mallard	*Anas platyrhynchos*	B	20	14	12	19	23	-31	31	5
Cinnamon Teal	*Anas cyanoptera*		18	-11	0	-30	-42	16	12	1
Northern Shoveler	*Anas clypeata*		-57	-37	-22	-22	2	70	15	3
Hooded Merganser	*Lophodytes cucullatus*	B	28	-1	0	-22	-29	19	31	10
Turkey Vulture	*Cathartes aura*		12	8	4	3	0	-19	54	79
California Condor	*Gymnogyps californianus*	E, FE	98	65	0	-120	-320	-11400	8	<1
Osprey	*Pandion haliaetus*	B	30	-1	-1	-25	-32	33	23	9
White-tailed Kite	*Elanus leucurus*		36	19	14	9	4	-271	23	18
Bald Eagle	*Haliaeetus leucocephalus*	B, O-T, F-T	32	-1	-1	-25	-35	30	35	11
Northern Harrier	*Circus cyaneus*		19	18	10	18	14	-21	23	33
Sharp-shinned Hawk	*Accipiter striatus*		4	0	0	-7	-13	11	42	62
Cooper's Hawk	*Accipiter cooperii*		4	0	0	-7	-13	11	46	63
Northern Goshawk	*Accipiter gentilis*	R, O-S, F-S	81	47	34	-9	-64	24	8	21
Red-tailed Hawk	*Buteo jamaicensis*		-5	-3	-4	3	11	-27	73	78
Golden Eagle	*Aquila chrysaetos*	R	-51	-35	-30	-11	25	31	12	23
American Kestrel	*Falco sparverius*		15	10	9	10	6	-50	50	53

Common Name	Scientific Name	Codes	Hi-D	Mod-D	Trend	Mod-C	Hi-C	1850s	% habitats	% area
Ring-necked Pheasant	*Phasianus colchicus*	I	21	14	9	10	4	-29	42	44
Blue Grouse	*Dendragapus obscurus*		2	1	-1	-1	1	33	19	42
Ruffed Grouse	*Bonasa umbellus*		54	32	26	0	-37	-25	27	32
Wild Turkey	*Meleagris gallopayo*	I	17	15	17	15	-4	-48	31	25
California Quail	*Callipepla californica*	I	-27	-20	-15	-7	9	-81	50	44
Mountain Quail	*Oreortyx pictus*		-58	-34	-29	7	50	-46	27	27
Virginia Rail	*Rallus limicola*		50	1	1	-52	-73	70	4	<1
Sora	*Porzana carolina*		50	1	1	-52	-73	70	4	<1
American Coot	*Fulica americana*		18	-11	0	-30	-42	16	12	1
Killdeer	*Charadrius vociferus*		12	13	8	25	37	-33	42	31
Spotted Sandpiper	*Actitis macularia*		8	-5	0	-13	-17	7	19	3
Common Snipe	*Gallinago gallinago*		50	1	1	-52	-73	70	4	<1
Marbled Murrelet	*Brachyramphus marmoratus*	O-T, F-T	76	30	27	-50	-124	-164	4	6
Rock Dove	*Columba livia*	I	12	15	9	30	44	100	19	29
Band-tailed Pigeon	*Columba fasciata*		3	1	-2	0	0	-15	35	48
Mourning Dove	*Zenaida macroura*		-12	-6	-7	8	23	-13	81	73
Yellow-billed Cuckoo	*Coccyzus americanus*	E, O-S	40	3	0	-29	-37	62	4	7
Barn Owl	*Tyto alba*		29	17	11	7	2	-85	31	40
Western Screech Owl	*Otus kennicottii*		22	4	13	1	-12	-144	19	16
Great Horned Owl	*Bubo virginianus*		-20	-18	-13	-16	-13	-41	42	40
Northern Pygmy Owl	*Glaucidium gnoma*	O-S	56	29	25	-7	-43	8	27	35
Burrowing Owl	*Athene cunicularia*	R, O-S, F-S	41	40	28	48	54	-458	8	7
Spotted Owl	*Strix occidentalis*	O-T, F-T	81	47	34	-9	-64	24	8	21
Barred Owl	*Strix varia*		37	10	15	-17	-42	-98	15	20
Long-eared Owl	*Asio otus*		21	4	9	-3	-13	-152	23	16
Short-eared Owl	*Asio flammeus*	R	42	37	26	40	44	-416	12	8
Northern Saw-whet Owl	*Aegolius acadicus*		1	0	-2	-3	1	31	15	41
Common Nighthawk	*Chordeiles minor*		-31	-22	-19	-1	30	-106	38	39
Vaux's Swift	*Chaetura vauxi*		30	5	0	-30	-53	-18	31	19
Anna's Hummingbird	*Calypte anna*		9	-1	8	-19	-51	-110	27	19
Rufous Hummingbird	*Selasphorus rufus*		4	0	-1	-12	-20	-71	46	56
Belted Kingfisher	*Ceryle alcyon*		31	1	0	-24	-32	47	23	9
Lewis' Woodpecker	*Melanerpes lewis*	R, O-S	32	6	5	-14	-26	-163	12	10
Acorn Woodpecker	*Melanerpes formicivorus*		17	11	14	13	-4	-558	12	4
Red-breasted Sapsucker	*Sphyrapicus ruber*		61	32	25	-9	-47	4	15	32
Downy Woodpecker	*Picoides pubescens*		21	4	13	-20	-60	-134	23	17
Hairy Woodpecker	*Picoides villosus*		8	2	-1	-5	-5	-9	27	51
Northern Flicker	*Colaptes auratus*		8	4	2	-1	-6	-33	54	71
Pileated Woodpecker	*Dryocopus pileatus*	O-S	56	29	24	-7	-41	-15	19	35
Olive-sided Flycatcher	*Contopus borealis*		1	0	-2	-3	1	31	15	41
Western Wood-Pewee	*Contopus sordidulus*		-46	-31	-25	-3	35	-24	23	32

Common Name	Scientific Name	Codes	Hi-D	Mod-D	Trend	Mod-C	Hi-C	1850s	% habitats	% area
Willow Flycatcher	*Empidonax traillii*		-43	-30	-22	0	38	21	19	31
Hammond's Flycatcher	*Empidonax hammondii*		1	0	-2	-3	1	31	15	41
Pacific-slope Flycatcher	*Empidonax difficilis*		56	29	24	-7	-41	-15	19	35
Western Kingbird	*Tyrannus verticalis*		22	20	12	10	-14	15	19	18
Horned Lark	*Eremophila alpestris*	O-S	19	17	12	27	34	-123	19	18
Purple Martin	*Progne subis*	R, O-S	18	-11	0	-30	-42	16	12	1
Tree Swallow	*Tachycineta bicolor*	B	29	1	2	-21	-29	33	31	10
Violet-green Swallow	*Tachycineta thalassina*		9	-8	-6	-23	-22	56	27	11
N. Rough-winged Swallow	*Stelgidopteryx serripennis*		8	-5	0	-13	-17	7	19	3
Cliff Swallow	*Hirundo pyrrhonota*		-38	-25	-15	-14	2	46	23	4
Barn Swallow	*Hirundo rustica*		-38	-25	-15	-14	2	46	23	4
Steller's Jay	*Cyanocitta stelleri*		1	0	-2	-3	1	31	15	41
Western Scrub-Jay	*Aphelocoma californica*		8	-2	7	-17	-45	-88	38	21
American Crow	*Corvus brachyrhynchos*		-13	-6	-7	7	24	-20	65	68
Common Raven	*Corvus corax*		11	6	2	2	4	43	31	56
Black-capped Chickadee	*Parus atricapillus*		-37	-26	-20	-10	8	-16	31	34
Chestnut-backed Chickadee	*Parus rufescens*		55	33	27	-5	-45	-4	15	27
Bushtit	*Psaltriparus minimus*		-62	-37	-27	-6	21	-34	35	28
Red-breasted Nuthatch	*Sitta canadensis*		60	35	30	-2	-42	-33	15	28
White-breasted Nuthatch	*Sitta carolinensis*		23	5	10	-3	-14	-167	15	15
Brown Creeper	*Certhia americana*		56	29	24	-7	-41	-15	19	35
Bewick's Wren	*Thryomanes bewickii*		-40	-28	-21	-10	9	-23	27	32
House Wren	*Troglodytes aedon*		-44	-30	-23	-1	34	-18	27	34
Winter Wren	*Troglodytes troglodytes*		1	0	-2	-3	1	31	15	41
Marsh Wren	*Cistothorus palustris*		50	1	1	-52	-73	70	4	<1
American Dipper	*Cinclus mexicanus*		0	0	0	0	0	0	4	<1
Golden-crowned Kinglet	*Regulus satrapa*		67	39	32	-4	-50	-11	12	25
Western Bluebird	*Sialia mexicana*	O-S	-32	-16	-14	17	52	2	23	38
Swainson's Thrush	*Catharus ustulatus*		6	1	-2	-11	-19	36	42	53
American Robin	*Turdus migratorius*		0	0	-1	0	0	-5	100	94
Varied Thrush	*Ixoreus naevius*		63	37	26	-4	-47	-11	19	27
Wrentit	*Chamaea fasciata*		-72	-43	-34	7	59	-26	15	22
Cedar Waxwing	*Bombycilla cedrorum*		-50	-34	-23	-14	4	6	65	45
Loggerhead Shrike	*Lanius ludovicianus*	R	30	27	22	10	-38	-29	19	12
European Starling	*Sturnus vulgaris*	I	-1	0	3	4	1	-45	81	56
Solitary Vireo	*Vireo solitarius*		60	35	30	-2	-42	-33	15	28
Hutton's Vireo	*Vireo huttoni*		55	28	25	-5	-41	-50	27	37
Warbling Vireo	*Vireo gilvus*		23	5	10	-3	-14	-167	15	15
Orange-crowned Warbler	*Vermivora celata*		-40	-28	-21	-10	9	-23	27	32
Yellow Warbler	*Dendroica petechia*	B	39	3	1	-27	-36	57	8	7
Yellow-rumped Warbler	*Dendroica coronata*		67	39	32	-4	-50	-11	12	25

Common Name	Scientific Name	Codes	Hi-D	Mod-D	Trend	Mod-C	Hi-C	1850s	% habitats	% area
Black-throated Gray Warbler	*Dendroica nigrescens*		3	1	-1	-1	0	-20	23	44
Hermit Warbler	*Dendroica occidentalis*		67	39	32	-4	-50	-11	12	25
Macgillivray's Warbler	*Oporornis tolmiei*		-76	-45	-35	7	64	42	12	21
Common Yellowthroat	*Geothlypis trichas*		20	10	7	10	14	-53	23	28
Wilson's Warbler	*Wilsonia pusilla*		-12	-5	-7	6	22	64	12	35
Yellow-breasted Chat	*Icteria virens*		31	3	7	-54	-120	71	12	9
Western Tanager	*Piranga ludoviciana*		60	35	30	-2	-42	-33	15	28
Black-headed Grosbeak	*Pheucticus melanocephalus*		51	26	23	-13	-59	-40	35	40
Lazuli Bunting	*Passerina amoena*		21	12	13	6	-11	-18	35	34
Spotted Towhee	*Pipilo maculatus*		-32	-22	-19	-6	12	5	42	44
Chipping Sparrow	*Spizella passerina*		-54	-31	-27	6	48	14	23	32
Vesper Sparrow	*Pooecetes gramineus*	O-S	26	24	15	35	38	0	12	15
Savannah Sparrow	*Passerculus sandwichensis*		19	17	10	26	34	-54	31	36
Grasshopper Sparrow	*Ammodramus savannarum*	R, O-S	19	9	0	-23	-61	-2100	12	3
Song Sparrow	*Melospiza melodia*		-34	-22	-20	-6	13	-5	81	59
White-crowned Sparrow	*Zonotrichia leucophrys*		-55	-37	-26	-16	4	27	46	41
Dark-eyed Junco	*Junco hyemalis*		2	1	0	2	5	46	27	51
Red-winged Blackbird	*Agelaius phoeniceus*		16	15	9	16	13	-11	46	38
Western Meadowlark	*Sturnella neglecta*		22	21	12	30	37	-103	23	27
Brewer's Blackbird	*Euphagus cyanocephalus*		-2	-1	0	0	-2	-26	65	47
Brown-headed Cowbird	*Molothrus ater*		9	6	3	4	3	-5	77	92
Bullock's Oriole	*Icterus bullockii*		12	-3	-1	-14	-17	-123	15	12
Purple Finch	*Carpodacus purpureus*		7	1	-1	-5	-3	20	23	50
House Finch	*Carpodacus mexicanus*		-4	-1	7	16	15	-71	27	16
Red Crossbill	*Loxia curvirostra*		67	39	32	-4	-50	-11	12	25
Pine Siskin	*Carduelis pinus*		7	1	-2	-6	-5	35	19	47
Lesser Goldfinch	*Carduelis psaltria*		23	21	23	36	28	-77	19	15
American Goldfinch	*Carduelis tristis*		-25	-14	-10	3	20	-17	62	68
Evening Grosbeak	*Coccothraustes vespertinus*		67	39	32	-4	-50	-11	12	25
House Sparrow	*Passer domesticus*	I	11	21	14	41	56	100	8	9

MAMMALS

Common Name	Scientific Name	Codes	Hi-D	Mod-D	Trend	Mod-C	Hi-C	1850s	% habitats	% area
Virginia opossum	*Didelphis virginiana*	I	-8	-8	-5	-12	-17	16	62	66
vagrant shrew	*Sorex vagrans*		2	1	1	0	-1	-9	62	87
Pacific shrew	*Sorex pacificus*		7	1	0	-4	-4	23	31	52
Pacific water or marsh shrew	*Sorex bendirii*	B	25	1	0	-20	-25	37	35	12

Common Name	Scientific Name	Codes	Hi-D	Mod-D	Trend	Mod-C	Hi-C	1850s	% habitats	% area
Trowbridge's shrew	*Sorex trowbridgii*		8	2	0	-4	-4	-6	31	52
fog shrew	*Sorex sonomae*		7	1	-1	-5	-4	21	27	51
shrew-mole	*Neurotrichus gibbsii*		2	1	0	0	2	16	23	45
Townsend's mole	*Scapanus townsendii*		-1	0	4	4	0	-49	62	53
coast mole	*Scapanus orarius*		11	5	4	-3	-9	32	46	62
little brown myotis	*Myotis lucifugus*		0	0	-1	1	1	37	96	94
yuma myotis	*Myotis yumanensis*	B, O-S, F-S	24	-1	-7	-19	-29	21	65	14
long-eared myotis	*Myotis evotis*	O-S, F-S	7	2	-1	-7	-14	8	65	65
fringed myotis	*Myotis thysanodes*	O-S, F-S	8	1	-1	-5	-5	-8	46	53
long-legged myotis	*Myotis volans*	O-S, F-S	51	26	19	-7	-39	-49	50	40
California myotis	*Myotis californicus*		7	2	-1	-7	-14	8	65	65
silver-haired bat	*Lasionycteris noctivagans*	O-S	4	0	-1	-3	0	8	54	63
big brown bat	*Eptesicus fuscus*		0	0	0	1	1	37	88	92
hoary bat	*Lasiurus cinereus*		54	28	23	-7	-42	-51	38	38
Tonwsend's big-eared bat	*Plecotus townsendii*	R, O-S, F-S	58	30	24	-9	-46	5	27	34
pallid bat	*Antrozous pallidus*	R, O-S	37	5	0	-24	-41	-108	19	9
brush rabbit	*Sylvilagus bachmani*		7	2	1	-7	-13	33	38	61
eastern cottontail	*Sylvilagus floridanus*	I	-45	-29	-23	-10	10	-33	50	43
snowshoe hare	*Lepus americanus*		2	1	0	0	2	16	23	45
black-tailed jack rabbit	*Lepus californicus*		19	18	12	30	37	-59	27	34
mountain beaver	*Aplodontia rufa*		2	1	0	1	6	26	23	51
Townsend's chipmunk	*Tamias townsendii*		8	2	-1	-11	-20	-7	31	52
California ground squirrel	*Spermophilus beecheyi*		12	13	9	17	13	-40	42	39
western gray squirrel	*Sciurus griseus*	O-S	57	30	24	-7	-43	-56	23	36
Douglas' squirrel (chickaree)	*Tamiasciurus douglasii*		67	39	32	-4	-50	-11	12	25
northern flying squirrel	*Glaucomys sabrinus*		48	25	21	-7	-38	-9	23	37
western pocket gopher	*Thomomys mazama*		-8	-3	-4	9	23	72	19	43
camas pocket gopher	*Thomomys bulbivorus*		-9	-1	1	7	5	-39	50	39
American beaver	*Castor canadensis*	B	9	-1	0	-9	-12	17	92	16
deer mouse	*Peromyscus maniculatus*		0	0	0	0	0	-6	69	90
dusky-footed woodrat	*Neotoma fuscipes*		21	4	13	-20	-60	-134	23	17
bushy-tailed woodrat	*Neotoma cinerea*		2	1	0	0	2	16	23	45
western red-backed vole	*Clethrionomys californicus*		2	1	-1	-1	2	14	19	44
white-footed vole	*Phenacomys albipes*	O-S, F-S	1	0	-2	-3	1	31	15	41
red tree vole	*Phenacomys longicaudus*		81	47	34	-9	-64	24	8	21
Townsend's vole	*Microtus townsendii*		22	19	15	26	24	-186	27	19
long-tailed vole	*Microtus longicaudus*		-76	-45	-35	7	64	42	12	21
creeping vole or Oregon vole	*Microtus oregoni*		7	1	0	-4	-3	22	27	52
gray-tailed vole	*Microtus canicaudus*		18	17	11	17	11	-49	35	37
common muskrat	*Ondatra zibethicus*		15	0	0	-16	-22	9	12	2
Norway rat	*Rattus norvegicus*	I	12	14	8	18	15	100	23	30

Common Name	Scientific Name	Codes	Hi-D	Mod-D	Trend	Mod-C	Hi-C	1850s	% habitats	% area
house mouse	*Mus musculus*	I	11	14	10	17	13	-27	31	31
pacific jumping mouse	*Zapus trinotatus*		7	1	-1	-5	-3	20	23	50
common porcupine	*Erethizon dorsatum*		-6	-7	-4	-7	-5	9	42	61
nutria	*Myocastor coypus*	B, I	19	13	12	14	9	-37	54	6
coyote	*Canis latrans*		9	6	3	4	3	-6	65	90
gray or timber wolf	*Canis lupus*	E, O-E, F-E	8	2	0	-5	-6	-79	38	53
red fox	*Vulpes vulpes*		-12	-6	-6	8	24	-14	58	69
gray fox	*Urocyon cinereoargenteus*		8	2	0	-11	-20	-4	38	54
black bear	*Ursus americanus*		8	1	0	-11	-21	-74	46	55
grizzly bear	*Ursus arctos*	E, FT	8	2	0	-5	-6	-77	46	54
common raccoon	*Procyon lotor*		8	3	1	-4	-9	-43	81	70
American marten	*Martes americana*	O-S	2	1	-1	-1	2	14	19	44
fisher	*Martes pennanti*	O-S, F-S	1	0	-2	-3	1	31	15	41
ermine or shorttail weasel	*Mustela erminea*		11	6	3	-1	-7	-35	54	70
long-tailed weasel	*Mustela frenata*		11	6	3	-1	-7	-35	54	70
mink	*Mustela vison*		30	1	0	-24	-31	48	19	10
western spotted skunk	*Spilogale gracilis*		7	1	0	-4	-3	22	27	52
striped skunk	*Mephitis mephitis*		-21	-13	-10	1	17	-51	54	52
northern river otter	*Lutra canadensis*		26	1	-8	-20	-26	39	31	11
mountain lion	*Felis concolor*		2	1	1	0	-1	-10	62	86
feral house cat	*Felis catus*	I	12	14	9	17	13	-44	35	38
lynx	*Lynx lynx*	E, F-S	7	1	-1	-5	-3	20	23	50
bobcat	*Lynx rufus*		11	6	4	0	-6	18	42	68
wapiti or elk	*Cervus elaphus*		2	1	1	0	-1	-10	65	86
mule or black-tailed deer	*Odocoileus hemionus*		0	0	0	0	0	-5	73	90
white-tailed deer	*Odocoileus virginianus*	E, O-E, F-E	-1	0	4	4	1	-46	62	54

Table 3. Local experts consulted about the species list (S; including extirpated, introduced, and rare species) and about species habitat associations (H). Experts provided information on one or more species of amphibians (A), reptiles (R), breeding birds (B), and/or mammals (M).

Name	Species	Subject	Affiliation
Paul Adamus	B	S, H	Wildlife Ecology Consultant, Corvallis, Oregon; Coordinator - Oregon Breeding Bird Atlas
Bob Altman	B	H	President, Avifauna Northwest, Boring, Oregon
Joe Beatty	R	H	Senior Instructor, Department of Zoology, Oregon State University, Corvallis, Oregon
Ray Bentley	M	S	Biologist, U.S. Geological Survey, Biological Resource Division, Corvallis, Oregon
Sandy Bryce	B	S	Biogeographer, Dynamac Corporation, Corvallis, Oregon
Bruce Bury	A	S	Zoologist, U.S. Geological Survey, Biological Resource Division, Corvallis, Oregon
Doug Cottam	B, M	H	District Wildlife Biologist, Oregon Department of Fish and Wildlife, NW Region Office, Corvallis, Oregon
Blair Csuti	A, B, M, R	S, H	Research Assoc., Dep't Fish and Wildlife Resources, Univ. Idaho, Moscow, Idaho; U.S. Fish and Wildlife Service, Portland, Oregon
Dan Edge	M	H	Associate Professor, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon
John Hayes	M	S, H	Assistant Professor, Department of Forest Science, Oregon State University, Corvallis, Oregon
Manuela Huso	B	S	Statistician, Department of Forest Science, Oregon State University, Corvallis, Oregon
Robert L. Jarvis	B	S	Professor, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon
A. Ross Kiester	A, R	S	Director of Biodiversity Research Consortium, U.S. Forest Service, Forestry Sciences Lab, Corvallis, Oregon
Karl Martin	M	H	Graduate Student, Department of Forest Science, Oregon State University, Corvallis, Oregon
Kathy Merrifield	B	S	Senior Research Assistant, Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oregon
Mark Meyers	M	S	Wildlife Biologist, U.S. Forest Service, Forestry Sciences Lab, Corvallis, Oregon
Maura Naughton	B	S, H	Wildlife Biologist, U.S. Fish and Wildlife Service, W.L. Finley National Wildlife Refuge, Corvallis, Oregon
S. Kim Nelson	B	S	Oregon Cooperative Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon
Deanna H. Olson	A, R	S, H	Research Ecologist, U.S. Forest Service, Forestry Sciences Lab, Corvallis, Oregon
David Vesely	A, R	S, H	Consulting Wildlife Biologist, Albany, Oregon
Jerry Wolff	M	S, H	Associate Professor, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon

Table 4. Species-habitat associations. An entry of "1" for a species-habitat combination means that the species is likely to use the habitat for breeding or feeding, during the breeding season; an entry of "B" indicates that the species uses the habitat only near water. An entry of "0" for a species-habitat combination means that the species is unlikely to use the habitat for breeding or feeding, during the breeding season. Numbers 1 - 26 in the column headings refer to wildlife habitat classes in Table 6.

AMPHIBIANS

		FOREST						WATER							OPEN/WOODY				AGRICULTURE							URBAN	
Common Name	Scientific Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
northwestern salamander	*Ambystoma gracile*	0	1	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
long-toed salamander	*Ambystoma macrodactylum*	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	0	1	0	0	1	1
clouded salamander	*Aneides ferreus*	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ensatina	*Ensatina eschscholtzii*	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Dunn's salamander	*Plethodon dunni*	0	B	B	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
western redback salamander	*Plethodon vehiculum*	1	1	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
roughskin newt	*Taricha granulosa*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	1	0	0	0	0	0	1
Pacific giant salamander	*Dicamptodon tenebrosus*	0	B	B	B	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
southern torrent salamander	*Rhyacotriton variegatus*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
tailed frog	*Ascaphus truei*	0	B	B	B	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific chorus frog	*Pseudacris regilla*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
red-legged frog	*Rana aurora*	0	B	B	B	B	1	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
bullfrog	*Rana catesbeiana*	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
spotted frog	*Rana pretiosa*	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

REPTILES

		FOREST						WATER							OPEN/WOODY				AGRICULTURE							URBAN	
Common Name	Scientific Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
painted turtle	*Chrysemys picta*	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	B	0	0	0	0	0	0
western pond turtle	*Clemmys marmorata*	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	B	B	0	0	B	0	0	0	0	0	0
slider	*Trachemys scripta*	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	B	0	0	0	0	0	0
northern alligator lizard	*Elgaria coerulea*	1	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0
southern alligator lizard	*Elgaria multicarinata*	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	1	1	0	0
western fence lizard	*Sceloporus occidentalis*	1	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	1	1	0	1
western skink	*Eumeces skiltonianus*	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1
rubber boa	*Charina bottae*	1	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1	0	1
racer	*Coluber constrictor*	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	0	1
sharptail snake	*Contia tenuis*	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1
ringneck snake	*Diadophis punctatus*	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1
gopher (pine) snake	*Pituophis melanoleucus*	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1
w. terrestrial garter snake	*Thamnophis elegans*	0	0	0	0	0	1	1	0	0	1	0	1	0	1	1	0	1	0	1	1	1	1	1	1	1	1
northwestern garter snake	*Thamnophis ordinoides*	1	1	1	1	1	1	1	0	0	1	0	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1
common garter snake	*Thamnophis sirtalis*	1	1	1	1	1	1	1	0	0	1	0	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1
western rattlesnake	*Crotalus viridis*	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0

				FOREST							WATER				OPEN/WOODY						AGRICULTURE					URBAN	
Common Name	Scientific Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
BREEDING BIRDS																											
Pied-billed Grebe	*Podilymbus podiceps*	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
American Bittern	*Botaurus lentiginosus*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Great Blue Heron	*Ardea herodias*	0	B	B	B	B	1	1	1	1	1	1	1	1	0	0	0	0	0	0	B	0	0	0	0	B	0
Green Heron	*Butorides virescens*	0	B	B	B	B	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Black-crowned Night-Heron	*Nycticorax nycticorax*	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Canada Goose	*Branta canadensis*	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	B	B	B	B	0	0	0	0	B	0
Wood Duck	*Aix sponsa*	0	0	0	B	B	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Mallard	*Anas platyrhynchos*	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	B	0	B	B	0	0	0	0	0	0
Cinnamon Teal	*Anas cyanoptera*	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Shoveler	*Anas clypeata*	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Hooded Merganser	*Lophodytes cucullatus*	0	0	B	B	B	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Turkey Vulture	*Cathartes aura*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	1	1	0	0	0	0	0	1
California Condor	*Gymnogyps californianus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Osprey	*Pandion haliaetus*	0	0	B	0	0	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
White-tailed Kite	*Elanus leucurus*	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0
Bald Eagle	*Haliaeetus leucocephalus*	0	B	B	B	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Harrier	*Circus cyaneus*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0	0	0	0	0
Sharp-shinned Hawk	*Accipiter striatus*	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	1	0
Cooper's Hawk	*Accipiter cooperii*	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	1	1	0
Northern Goshawk	*Accipiter gentilis*	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-tailed Hawk	*Buteo jamaicensis*	1	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	1	1	0	0	0	1	1
Golden Eagle	*Aquila chrysaetos*	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
American Kestrel	*Falco sparverius*	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	1	1	1	0	0	0	1	1
Ring-necked Pheasant	*Phasianus colchicus*	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	1
Blue Grouse	*Dendragapus obscurus*	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ruffed Grouse	*Bonasa umbellus*	0	1	1	1	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Wild Turkey	*Meleagris gallopayo*	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	0	0	1	0	0
California Quail	*Callipepla californica*	1	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	0	0	1	0	0	1	0	1
Mountain Quail	*Oreortyx pictus*	1	0	0	1	1	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Virginia Rail	*Rallus limicola*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sora	*Porzana carolina*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
American Coot	*Fulica americana*	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Killdeer	*Charadrius vociferus*	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	1	1
Spotted Sandpiper	*Actitis macularia*	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Snipe	*Gallinago gallinago*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marbled Murrelet	*Brachyramphus màrmoratus*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Dove	*Columba livia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	1
Band-Tailed Pigeon	*Columba fasciata*	1	1	1	1	1	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Mourning Dove	*Zenaida macroura*	1	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1
Yellow-billed Cuckoo	*Coccyzus americanus*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Barn Owl	*Tyto alba*	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	1	0
Western Screech Owl	*Otus kennicottii*	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Great Horned Owl	*Bubo virginianus*	1	0	1	1	1	1	1	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Northern Pygmy Owl	*Glaucidium gnoma*	0	1	1	1	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Burrowing Owl	*Athene cunicularia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
Spotted Owl	*Strix occidentalis*	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Barred Owl	*Strix varia*	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long-eared Owl	*Asio otus*	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Common Name	Scientific Name	FOREST 1	2	3	4	5	6	WATER 7	8	9	10	11	12	13	OPEN/WOODY 14	15	16	17	AGRICULTURE 18	19	20	21	22	23	24	URBAN 25	26
Short-eared Owl	*Asio flammeus*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
Northern Saw-whet Owl	*Aegolius acadicus*	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Nighthawk	*Chordeiles minor*	1	0	0	1	1	1	1	0	0	0	0	1	1	0	0	1	1	0	0	0	1	0	0	0	0	0
Vaux's Swift	*Chaetura vauxi*	0	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Anna's Hummingbird	*Calypte anna*	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0
Rufous Hummingbird	*Selasphorus rufus*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	1	0
Belted Kingfisher	*Ceryle alcyon*	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lewis' Woodpecker	*Melanerpes lewis*	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Acorn Woodpecker	*Melanerpes formicivorus*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Red-breasted Sapsucker	*Sphyrapicus ruber*	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Downy Woodpecker	*Picoides pubescens*	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Hairy Woodpecker	*Picoides villosus*	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Northern Flicker	*Colaptes auratus*	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	1	1
Pileated Woodpecker	*Dryocopus pileatus*	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Olive-sided Flycatcher	*Contopus borealis*	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Wood-Pewee	*Contopus sordidulus*	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Willow Flycatcher	*Empidonax traillii*	1	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hammond's Flycatcher	*Empidonax hammondii*	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific-slope Flycatcher	*Empidonax difficilis*	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Kingbird	*Tyrannus verticalis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1
Horned Lark	*Eremophila alpestris*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	1
Purple Martin	*Progne subis*	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Tree Swallow	*Tachycineta bicolor*	0	0	0	B	B	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Violet-green Swallow	*Tachycineta thalassina*	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0
N. Rough-winged Swallow	*Stelgidopteryx serripennis*	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cliff Swallow	*Hirundo pyrrhonota*	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Barn Swallow	*Hirundo rustica*	0	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Steller's Jay	*Cyanocitta stelleri*	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Scrub-Jay	*Aphelocoma californica*	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	1
American Crow	*Corvus brachyrhynchos*	1	0	0	1	1	1	1	0	0	1	1	0	0	0	1	1	1	1	1	1	1	0	1	1	1	0
Common Raven	*Corvus corax*	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Black-capped Chickadee	*Parus atricapillus*	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1
Chestnut-backed Chickadee	*Parus rufescens*	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Bushtit	*Psaltriparus minimus*	1	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0
Red-breasted Nuthatch	*Sitta canadensis*	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White-breasted Nuthatch	*Sitta carolinensis*	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Brown Creeper	*Certhia americana*	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bewick's Wren	*Thryomanes bewickii*	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
House Wren	*Troglodytes aedon*	1	0	0	1	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0
Winter Wren	*Troglodytes troglodytes*	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marsh Wren	*Cistothorus palustris*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
American Dipper	*Cinclus mexicanus*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Golden-crowned Kinglet	*Regulus satrapa*	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Bluebird	*Sialia mexicana*	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0
Swainson's Thrush	*Catharus ustulatus*	1	1	1	1	0	1	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
American Robin	*Turdus migratorius*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Varied Thrush	*Ixoreus naevius*	0	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wrentit	*Chamaea fasciata*	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Cedar Waxwing	*Bombycilla cedrorum*	1	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	0
Loggerhead Shrike	*Lanius ludovicianus*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	1

		FOREST						WATER							OPEN/WOODY				AGRICULTURE							URBAN	
Common Name	Scientific Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
European Starling	*Sturnus vulgaris*	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Solitary Vireo	*Vireo solitarius*	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hutton's Vireo	*Vireo huttoni*	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Warbling Vireo	*Vireo gilvus*	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Orange-crowned Warbler	*Vermivora celata*	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Yellow Warbler	*Dendroica petechia*	0	0	0	0	B	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow-rumped Warbler	*Dendroica coronata*	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black-throated Gray Warbler	*Dendroica nigrescens*	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Hermit Warbler	*Dendroica occidentalis*	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macgillivray's Warbler	*Oporornis tolmiei*	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Common Yellowthroat	*Geothlypis trichas*	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1
Wilson's Warbler	*Wilsonia pusilla*	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow-breasted Chat	*Icteria virens*	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Western Tanager	*Piranga ludoviciana*	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black-headed Grosbeak	*Pheucticus melanocephalus*	0	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1
Lazuli Bunting	*Passerina amoena*	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	1
Spotted Towhee	*Pipilo maculatus*	1	0	0	1	1	1	0	1	1	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	1	0
Chipping Sparrow	*Spizella passerina*	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1
Vesper Sparrow	*Pooecetes gramineus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0
Savannah Sparrow	*Passerculus sandwichensis*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	1
Grasshopper Sparrow	*Ammodramus savannarum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1
Song Sparrow	*Melospiza melodia*	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
White-crowned Sparrow	*Zonotrichia leucophrys*	1	0	0	1	0	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	1	1	1	1	1
Dark-eyed Junco	*Junco hyemalis*	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1
Red-winged Blackbird	*Agelaius phoeniceus*	0	0	0	0	0	0	1	0	0	1	1	1	1	0	1	0	1	1	1	1	1	0	0	0	0	1
Western Meadowlark	*Sturnella neglecta*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	1
Brewer's Blackbird	*Euphagus cyanocephalus*	0	0	0	0	0	1	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1
Brown-headed Cowbird	*Molothrus ater*	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1
Bullock's Oriole	*Icterus bullockii*	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Purple Finch	*Carpodacus purpureus*	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
House Finch	*Carpodacus mexicanus*	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	1	1	0
Red Crossbill	*Loxia curvirostra*	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pine Siskin	*Carduelis pinus*	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lesser Goldfinch	*Carduelis psaltria*	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1
American Goldfinch	*Carduelis tristis*	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1
Evening Grosbeak	*Coccothraustes vespertinus*	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
House Sparrow	*Passer domesticus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0

MAMMALS

		FOREST						WATER							OPEN/WOODY				AGRICULTURE							URBAN	
Common Name	Scientific Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Virginia opossum	*Didelphis virginiana*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	1	0	0	1	1	0	1	1	1
vagrant shrew	*Sorex vagrans*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0	0	0	1
Pacific shrew	*Sorex pacificus*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Pacific water or marsh shrew	*Sorex bendirii*	B	B	B	B	B	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trowbridge's shrew	*Sorex trowbridgii*	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
fog shrew	*Sorex sonomae*	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
shrew-mole	*Neurotrichus gibbsii*	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

		FOREST						WATER							OPEN/WOODY				AGRICULTURE							URBAN	
Common Name	Scientific Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Townsend's mole	*Scapanus townsendii*	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1
coast mole	*Scapanus orarius*	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0
little brown myotis	*Myotis lucifugus*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
yuma myotis	*Myotis yumanensis*	0	B	B	B	B	1	1	1	1	1	1	1	1	B	B	B	0	0	0	0	B	0	0	0	B	0
long-eared myotis	*Myotis evotis*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0
fringed myotis	*Myotis thysanodes*	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0
long-legged myotis	*Myotis volans*	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0
California myotis	*Myotis californicus*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0
silver-haired bat	*Lasionycteris noctivagans*	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	0	0	0	0	1	0	0	0	1	0
big brown bat	*Eptesicus fuscus*	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
hoary bat	*Lasiurus cinereus*	0	1	1	1	1	1	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Tonwsend's big-eared bat	*Plecotus townsendii*	0	1	1	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pallid bat	*Antrozous pallidus*	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
brush rabbit	*Sylvilagus bachmani*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0
eastern cottontail	*Sylvilagus floridanus*	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1	0	1	1	0
snowshoe hare	*Lepus americanus*	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
black-tailed jack rabbit	*Lepus californicus*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	0	0	0	0	0
mountain beaver	*Aplodontia rufa*	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Townsend's chipmunk	*Tamias townsendii*	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
California ground squirrel	*Spermophilus beecheyi*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1
western gray squirrel	*Sciurus griseus*	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Douglas' squirrel (chickaree)	*Tamiasciurus douglasii*	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
northern flying squirrel	*Glaucomys sabrinus*	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
western pocket gopher	*Thomomys mazama*	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
camas pocket gopher	*Thomomys bulbivorus*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
American beaver	*Castor canadensis*	B	B	B	B	B	1	1	0	0	1	1	1	1	B	B	B	B	B	B	B	B	B	B	B	B	B
deer mouse	*Peromyscus maniculatus*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1
dusky-footed woodrat	*Neotoma fuscipes*	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
bushy-tailed woodrat	*Neotoma cinerea*	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
western red-backed vole	*Clethrionomys californicus*	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white-footed vole	*Phenacomys albipes*	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
red tree vole	*Phenacomys longicaudus*	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Townsend's vole	*Microtus townsendii*	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	1	1	0	0	0	0	1
long-tailed vole	*Microtus longicaudus*	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
creeping or Oregon vole	*Microtus oregoni*	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
gray-tailed vole	*Microtus canicaudus*	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	1	1	0	0	0	0	1
common muskrat	*Ondatra zibethicus*	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Norway rat	*Rattus norvegicus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	1	1
house mouse	*Mus musculus*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	0	0	0	0	1	1
pacific jumping mouse	*Zapus trinotatus*	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
common porcupine	*Erethizon dorsatum*	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	1	0	0	0	0
nutria	*Myocastor coypus*	0	0	0	0	B	0	1	0	0	1	0	1	0	B	B	B	B	B	B	B	0	0	0	B	B	B
coyote	*Canis latrans*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	1	1
gray or timber wolf	*Canis lupus*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0
red fox	*Vulpes vulpes*	1	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	1	1
gray fox	*Urocyon cinereoargenteus*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
black bear	*Ursus americanus*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0
grizzly bear	*Ursus arctos*	1	1	1	1	1	1	1	0	0	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0
common raccoon	*Procyon lotor*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1
American marten	*Martes americana*	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Common Name	Scientific Name	FOREST 1	2	3	4	5	6	WATER 7	8	9	10	11	12	13	OPEN/WOODY 14	15	16	17	AGRICULTURE 18	19	20	21	22	23	24	URBAN 25	26
fisher	*Martes pennanti*	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ermine or shorttail weasel	*Mustela erminea*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	0	1
long-tailed weasel	*Mustela frenata*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	0	1
mink	*Mustela vison*	0	0	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
western spotted skunk	*Spilogale gracilis*	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
striped skunk	*Mephitis mephitis*	1	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	0	0	1	1
northern river otter	*Lutra canadensis*	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
mountain lion	*Felis concolor*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0
feral house cat	*Felis catus*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	0	0	0	1	1
lynx	*Lynx lynx*	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bobcat	*Lynx rufus*	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	0
wapiti or elk	*Cervus elaphus*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	0	0
mule or black-tailed deer	*Odocoileus hemionus*	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1
white-tailed deer	*Odocoileus virginianus*	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1

Table 5. Definitions for Pre-Settlement vegetation classes, derived from the Oregon Natural Heritage Program and The Nature Conservancy (John Christy, personal communication, July 1996 version).

FALW	Ash-alder-willow swamp.
FAW	Ash-willow swamp.
FED	Inseparable mixture of (1) xeric Douglas fir - chinquapin-madrone on S slopes and ridge tops, and (2) more mesic Douglas fir-western hemlock or Douglas fir - bigleaf maple on N slopes and bottoms, sometimes with incense cedar, oak, grand fir, red cedar, yew, red alder, and dogwood.
FF	Douglas fir forest, possibly with some grand fir.
FFA	Ash riparian forest, often with Douglas fir, bigleaf maple, black cottonwood, red alder, willow and grand fir; sometimes with red cedar; understory includes hazel, ninebark, vine maple, dogwood, viburnum and yew.
FFHC	Douglas fir-western hemlock-red cedar (bigleaf maple) forest, sometimes with yew.
FO	White oak forest; closed canopy.
FOA	White oak-ash riparian forest, sometimes with cottonwood and willow.
OFOZ	Douglas fir and white oak woodland "scattering" or "thinly timbered," with brushy understory of hazel, oak sprouts, bracken and other shrubs; differs from SOF in having brushy understory.
OFZ	Sparse Douglas fir woodland ("timber") with brushy understory of hazel, bracken and other shrubs, but lacking oaks.
SO	White oak savanna.
SOF	White oak-Douglas fir savanna, mostly herbaceous understory.
SOP	White oak-ponderosa pine savanna.
P	Prairie, wet & dry, undifferentiated.
WSU	Swamp/marsh, composition unknown.

Table 6. Cross-reference between mapped land cover classes, wildlife habitat classes, and Pre-Settlement vegetation classes for the Muddy Creek watershed. L (lowland) and U (upland) indicate land cover classes that have been split into lowland and upland habitat classes. "-" indicates a land cover class that is not considered as a wildlife habitat class and has no species assigned to it. "0" indicates land cover or habitat classes that are not present in the Pre-Settlement map. Codes for the Pre-Settlement vegetation classes (FF, etc.) are defined in Table 5. Additional classes for the Pre-Settlement map (stream and open water classes) were added from the present-day land cover classes.

Land Cover Class	Wildlife Habitat Class	Pre-Settlement Vegetation Class
FORESTS		
0-40 yr Doug fir	1 0-40 yr Doug fir (clearcuts)	0
41-80 yr Doug fir	2 41-120 yr Doug fir	0
81-120 yr Doug fir	2 41-120 yr Doug fir	0
120+ yr Doug fir	3 120+ yr Doug fir	Mature Fir Forest (FF-FFHC-OFZ)
Mixed conifer	4 Mixed conifer/deciduous	Mixed conifer/deciduous (FED)
Oak & other hardwood	5 Oak & other hardwood	Oak Forest (FO-OFOZ)
Wet riparian with trees	6 Lowland Deciduous Riparian	Swamp/Riparian (FAW-FALW-FFA-FOA)
WATER		
Non-treed wetlands - marsh	7 Lowland Herbaceous Marsh	Lowland Marsh (WSU)
Streams (1st order) - L	8 Streams (1st order) - L	Streams (1st order) - L
Streams (1st order) - U	9 Streams (1st order) - U	Streams (1st order) - U
Intermittent streams - L	-	Intermittent streams - L
Intermittent streams - U	9 Streams (1st order) - U	Intermittent streams - U
Streams (2+ order) - L	10 Streams (2+ order) - L	Streams (2+ order) - L
Streams (2+ order) - U	11 Streams (2+ order) - U	Streams (2+ order) - U
Open standing water - L	12 Open standing water - L	Open standing water - L
Open standing water - U	13 Open standing water - U	Open standing water - U
OPEN/WOODY		
Shrub/brush	14 Shrub/brush	0
Hedgerows/Woody Roadsides	15 Woody Hedgerows	0
Oak Savanna	16 Oak Savanna	Oak Savanna (SO-SOF-SOP)
Prairie	17 Prairie	Prairie (P)
AGRICULTURE		
Row Crops	18 Row Crops	0
Grass Seed/Grain	19 Grass Seed/Grain	0
Pasture	20 Pasture	0
Xmas Tree	21 Xmas Tree	0
Hybrid Poplar for Pulp	22 Hybrid Poplar	0
Hybrid Poplar for Veneer	22 Hybrid Poplar	0
Orchards	23 Orchards	0
Vineyards	24 Vineyards	0
ROADS/URBAN		
Commercial	25 Urban	0
W/in 2 acres of structures	25 Urban	0
Primary Roads - L	26 Herbaceous Roadside	0
Secondary Highway - L	26 Herbaceous Roadside	0
Light duty road - L	26 Herbaceous Roadside	0
Light duty road - U	-	0
Unimproved road - L	26 Herbaceous Roadside	0
Unimproved road - U	-	0
Trail - U	-	0
Railroad	15 Woody Hedgerows	0

Table 7. Percentage of the present, future, and past landscapes in each wildlife habitat class for the Muddy Creek watershed. Total area in the watershed is 32,300 hectares. Values were rounded to the nearest 0.1%. Some totals do not add up to 100.0% due to rounding errors.

#	Wildlife Habitat	Present %	Hi-D %	Mod-D %	Trend %	Mod-C %	Hi-C %	1850s %
1	0-40 yr Doug fir (clearcuts)	15.3	31.6	25.0	24.3	15.4	2.4	0.0
2	41-120 yr Doug fir	14.7	2.5	6.7	9.3	13.7	20.6	0.0
3	120+ yr Doug fir	6.0	1.4	4.2	4.3	8.9	13.3	15.7
4	Mixed conifer/deciduous	4.4	4.3	4.4	3.5	3.5	3.8	12.2
5	Oak & other hardwood	3.2	3.0	3.1	2.7	2.8	2.6	9.8
6	Lowland Deciduous Riparian	6.7	4.0	6.5	6.7	8.6	9.2	2.5
7	Lowland Herbaceous Marsh	0.6	0.3	0.6	0.6	0.9	1.1	0.2
8	Streams (1st order) [lowland]	0.2	0.2	0.2	1.1	0.2	0.2	0.2
9	Streams (≤ 1st order) [upland]	1.7	1.7	1.7	1.7	1.7	1.7	1.7
10	Streams (2+ order) [lowland]	1.1	1.1	1.1	1.1	1.1	1.1	1.1
11	Streams (2+ order) [upland]	0.4	0.4	0.4	0.4	0.4	0.4	0.4
12	Open standing water [lowland]	0.3	0.3	0.3	0.3	0.3	0.3	0.6
13	Open standing water [upland]	0.1	0.2	0.2	0.1	0.1	0.1	0.1
14	Shrub/brush	1.4	1.3	1.4	0.8	0.8	1.3	0.0
15	Woody Hedgerows	0.7	0.7	0.7	0.7	4.1	8.9	0.0
16	Oak Savanna	0.5	0.0	0.2	0.5	0.5	1.3	15.0
17	Prairie	0.0	0.0	0.0	0.0	0.6	0.7	39.4
18	Row Crops	1.1	1.1	1.2	1.1	1.0	0.9	0.0
19	Grass Seed/Grain	16.8	14.4	14.2	15.6	11.9	9.4	0.0
20	Pasture	7.1	4.2	4.2	5.1	3.1	2.5	0.0
21	Xmas Tree	7.5	7.0	7.1	7.3	6.3	5.5	0.0
22	Hybrid Poplar	0.0	8.2	5.3	3.0	3.7	3.2	0.0
23	Orchards	0.1	0.1	0.1	0.1	0.1	0.0	0.0
24	Vineyards	0.2	0.2	0.2	0.2	0.1	0.1	0.0
25	Urban	1.9	3.8	2.9	2.6	2.2	1.4	0.0
26	Herbaceous Roadside	2.0	2.0	2.1	2.0	2.0	2.0	0.0
	Not wildlife habitat	6.0	6.0	6.1	5.1	6.0	6.0	1.0
	Total	100.0	100.0	100.1	100.2	100.0	100.0	99.9

Table 8. Risk to habitat area, compared to the present, for taxonomic groups of native species (excluding introduced "I" and extirpated "E" species); n = number of species in the group. Risk is represented by geometric mean proportion at risk, given in percents (rounded to the nearest whole percent). Values > 0% indicate habitat loss (risk) compared to the present; values < 0% indicate habitat gain (improvement) compared to the present. See Figure 11 for a graphic summary of risk to major taxonomic groups.

	Hi-D %	Mod-D %	Trend %	Mod-C %	Hi-C %	1850s %
all native vertebrates (n=214)	**19**	**5**	**4**	**-4**	**-6**	**-9**
native amphibians (n=12)	**29**	**7**	**4**	**-8**	**-19**	**-12**
salamanders (n=9)	31	10	7	-6	-18	-14
frogs (n=3)	22	-3	-3	-15	-24	-6
native reptiles (n=15)	**-3**	**-2**	**1**	**0**	**-1**	**-65**
turtles (n=2)	27	17	15	12	9	-18
lizards (n=4)	-15	-8	-3	1	6	-106
snakes (n=9)	-5	-5	-1	-4	-6	-60
native birds (n=126)	**21**	**6**	**5**	**-4**	**-6**	**-8**
herons (n=5)	47	7	6	-32	-52	27
ducks (n=8)	14	-5	1	-13	-13	21
hawks (n=12)	24	10	6	-2	-8	-8
grouse (n=3)	11	3	1	2	12	-7
shorebirds (n=7)	30	4	3	-12	-14	31
dove/pigeon (n=2)	-4	-2	-4	4	12	-14
owls (n=10)	37	20	16	7	-2	-84
hummingbirds (n=2)	7	-1	4	-15	-34	-90
woodpeckers (n=7)	32	13	12	-6	-25	-81
flycatchers (n=6)	6	1	-1	-1	7	12
swallows (n=8)	2	-11	-6	-18	-13	20
crows/jays (n=4)	2	0	0	-2	-1	3
misc. forest-insect eaters (n=8)	28	10	9	-4	-5	-32
wrens (n=4)	0	-13	-11	-15	-1	26
thrushes (n=5)	9	2	-1	0	6	7
vireos (n=3)	48	24	22	-3	-32	-75
warblers (n=9)	23	6	4	-7	-4	26
tanagers/grosbeaks (n=4)	53	29	25	-3	-39	-25
sparrows (n=7)	-6	-3	-6	5	17	-43
blackbirds (n=5)	12	8	5	8	9	-46
finches (n=7)	11	4	5	5	4	-10
native mammals (n=61)	**16**	**6**	**3**	**-2**	**-6**	**1**
shrews/moles (n=8)	8	2	1	-4	-5	11
bats (n=11)	27	9	6	-8	-19	-1
rabbits/hares (n=3)	9	7	4	9	11	4
large rodents (n=4)	5	-1	-1	-7	-8	15
squirrels/gophers (n=7)	32	16	13	1	-12	-2
voles/mice (n=11)	16	7	4	2	4	-3
coyotes/foxes (n=3)	2	1	-1	1	4	-8
bears/raccoons (n=2)	8	2	1	-7	-15	-57
weasels (n=8)	10	0	-2	-6	-6	11
cats (n=2)	7	4	2	0	-3	5
deer/elk (n=2)	1	1	0	0	0	-8

Table 9. Risk to habitat area, compared to the present, within other groups of species: introduced species (I; see text for explanation of 1850s value); extirpated species (E); rare species (R); vulnerable species with Oregon or Federal conservation status (V; excluding extirpated and introduced species); habitat specialists and generalists (excluding extirpated and introduced species). Habitat specialists and generalists are defined here as those species using ≤ 10% and ≥ 70%, respectively, of wildlife habitat classes in Table 6. See Table 2 for species that are associated with each group; n = number of species in the group. Risk is represented by geometric mean proportion at risk, given in percents (rounded to the nearest whole percent). Values > 0% indicate habitat loss (risk) compared to the present; values < 0% indicate habitat gain (improvement) compared to the present. See Figures 13 and 14 for a graphic summary of the risk to these groups.

	Hi-D %	Mod-D %	Trend %	Mod-C %	Hi-C %	1850s %
Introduced Species (n=14)	7	7	5	11	13	-21
Extirpated Species (n=8)	49	13	1	-21	-35	-68
Rare Species (n=10)	38	19	13	2	-10	-112
Vulnerable Species (n=32)	36	14	10	-3	-13	-25
Habitat Specialists (n=14)	59	22	16	-19	-43	31
Habitat Generalists (n=14)	-2	-2	-2	-1	1	-4

Table 10. Native species at risk of losing ≥ 50% of their habitat in at least one of the possible future scenarios (18%, or 41 out of 222 native species). * indicates species at risk of losing 50 - 75% of habitat in the specified landscape; ** indicates 75 - 90% habitat loss; and *** indicates > 90% habitat loss. See Table 2 for scientific names and risk values. See Tables 1 and 2 for definitions of V (vulnerable; O = Oregon status, F = Federal status), R (rare), and E (extirpated).

Species	V	R	E	Hi-D	Mod-D	Trend	Mod-C	Hi-C
northwestern salamander				*				
clouded salamander	O			**				
American Bittern				*				
California Condor	F		E	***	*			
Northern Goshawk	O, F	R		**				
Ruffed Grouse				*				
Mountain Quail								*
Virginia Rail				*				
Sora				*				
Common Snipe				*				
Marbled Murrelet	O, F			**				
Northern Pygmy Owl	O			*				
Burrowing Owl	O, F	R						*
Spotted Owl	O, F			**				
Red-breasted Sapsucker				*				
Pileated Woodpecker	O			*				
Pacific-slope Flycatcher				*				
Chestnut-backed Chickadee				*				
Red-breasted Nuthatch				*				
Brown Creeper				*				
Marsh Wren				*				
Golden-crowned Kinglet				*				
Western Bluebird	O							*
Varied Thrush				*				
Wrentit								*
Solitary Vireo				*				
Hutton's Vireo				*				
Yellow-rumped Warbler				*				
Hermit Warbler				*				
Macgillivray's Warbler								*
Western Tanager				*				
Black-headed Grosbeak				*				
Red Crossbill				*				
Evening Grosbeak				*				
long-legged myotis	O, F			*				
hoary bat				*				
Tonwsend's big-eared bat	O, F	R		*				
western gray squirrel	O			*				
Douglas' squirrel				*				
red tree vole				**				
long-tailed vole								*

Table 11. Native species that have lost ≥ 50% of their habitat since the 1850s (12%, or 27 out of 222 native species). In Table 2, these species have risk values of ≤ -100%, indicating that they had at least 100% more, or a doubling, of habitat in the past compared to the present (or only half the habitat today, compared to the past), where risk value = 1 - [past habitat area/present habitat area] x 100. * indicates species that have lost 50 - 75% since the 1850s, or only 1/4 to 1/2 of habitat remaining (risk values between [(1-2) x 100] = -100 and [(1-4) x 100] = -300 in Table 2). ** indicates 75 - 90% habitat lost since the 1850s, or only 1/4 to 1/10 of habitat remaining (risk values between [(1-4) x 100] = -300 and [(1-10) x 100] = -900 in Table 2). *** indicates > 90% habitat lost, or < 1/10 of habitat remaining (risk values of [(1->10) x 100] = < -900 in Table 2). See Table 2 for scientific names and risk values. See Tables 1 and 2 for definitions of V (vulnerable; O = Oregon status, F = Federal status), R (rare), and E (extirpated).

Species	V	R	E	1850s
western pond turtle	O, F			*
southern alligator lizard				**
western fence lizard				*
rubber boa				*
gopher snake				*
western rattlesnake				*
California Condor	F		E	***
White-tailed Kite				*
Marbled Murrelet	O, F			*
Western Screech Owl				*
Burrowing Owl	O, F	R		**
Long-eared Owl				*
Short-eared Owl		R		**
Common Nighthawk				*
Anna's Hummingbird				*
Lewis' Woodpecker	O	R		*
Acorn Woodpecker				**
Downy Woodpecker				*
Horned Lark	O			*
White-breasted Nuthatch				*
Warbling Vireo				*
Grasshopper Sparrow	O	R		***
Western Meadowlark				*
Bullock's Oriole				*
pallid bat	O	R		*
dusky-footed woodrat				*
Townsend's vole				*