HABITAT MODELING: SPATIAL LANDSCAPE ASSESSMENT AT THE RIGDEN MINE, COLORADO[1]

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Abstract. Reclamation specialists are interested in assessing the landscape potential for many organisms through the use of wildlife habitat models to minimize the impacts of mining operations during the life of the mine. In this study, ten United States Fish and Wildlife Service habitat models (tree squirrels [*Sciurus* sp.], downy woodpecker [*Dendrocopus pubescens*], black-capped chickadee [*Parus atricapillus*], Eastern cottontail [*Sylvilagus floridanus*], snapping turtle [*Chelydra serpentina*], great blue heron [*Ardea herodias*], Western grebe *[Aechmophorus occidentalis*], red-winged blackbird [*Agelaius phoeniceus*], belted kingfisher [*Ceryle alcyon*], and American coot [*Fulica americana*]), were examined in a model validation experiment across ten cover types (76-100% canopy, 51-75% canopy, 26-50% canopy, grassland/urban savanna, exposed substrate, saplings, seedlings, shallow water/mudflats, water deeper than 2', and river) at the Rigden Mine near Fort Collins, Colorado for one year during 1989 through 1990. In addition, a second experiment tested for differences across the ten habitat models during carefully managed progressive mining operations by applying the predictive models for the management years 1975 (pre-mine), 1977, 1979, 1981, 1986, 1996, and 2036 (post-mining). The analysis revealed that the habitat scores significantly ($p \leq 0.05$) predicted actual observed habitat use, but only explained 32 percent of the variance. There were no significant differences in the habitat quality across the pre-mine, mine operations, and post-mine landscapes. This study suggests that there is still much work to be conducted to refine predictive wildlife habitat models, but that there is great potential for mining operations to minimize the impacts to wildlife during the life of the mine.

Additional Key Words: ecological planning, landscape architecture, wildlife planning, resource development

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[1]Paper was presented at the 2003 National Meeting of the American Society of Mining and Reclamation, and The 9th Billings Land Reclamation Symposium, Billings MT, June 3-6, 2003. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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Proceedings America Society of Mining and Reclamation, 2003 pp 103-118
DOI: 10.21000/JASMR03010103

https://doi.org/10.21000/JASMR03010103

Introduction

Environmental planners and designers are interested in spatial models to study the effects of various proposed, existing, and past biospheric and noospheric (Naveh and Lieberman 1984) treatments across a multiplicity of organisms, chemical conditions, and ecological indicators. In this instance, the use of the term "treatments" is meant in the statistical and experimental design sense, as expressed by Hicks (1982), where a treatment is defined as a specific condition concerning the contents and structure of space including not only bio-chemical-physical states but also economic conditions, psychological states and beliefs, and social constructs. Therefore environmental planners, designers, and scientists may examine and assess various biospheric treatments. One modeling tool that might be used in the assessment of these biospheric treatments is associated with wildlife habitat procedures, a quantitative methodology that developed in the late 1970s and early 1980s with numerous practical applications (USFWS 1982, USFWS 1981, USFWS 1980a and 1980b, U.S. Army Corps of Engineers 1980, Lines and Perry 1978, Flood *et al.* 1977, Russell et al. undated). This paper describes the use of wildlife habitat procedures to study the effects of spatial treatments in a Colorado surface mine application.

Emergence and Developmental Context of Environmental Science and Planning

At one time, environmental planners and designers had very few, if any, science based models to use in their professional practice efforts. When the early landscape planning movement gained momentum in the United States of America during the 1850s, most modern sciences did not yet exist. Most fundamental scientific analytic statistical techniques employed today, such as analysis of variance, regression analysis, linear programming, Chi-square tests for independence, and principal component analysis, had not yet been derived. Concepts concerning geological time based upon Hutton (1795) and Lyell (1830) were still being debated. Only a select few intellectuals knew about evolutionary concepts until 1859 (Darwin abridged 1979). In the United States of America, there were no programs in engineering, planning, or landscape architecture taught at any university. The formative practice of modern landscape/environmental planning developed at a time when heuristic decision making dominated the design arts (1850s), with the profession of architecture being the primary model to emulate. By the 1920s the profession of planning had fully emerged, founded upon principles of intellectually based analytic procedures; yet, much of the early landscape/environmental planning efforts were based upon paradigms lacking scientific support because there were no scientists addressing many of these issues from the 1850s to the 1930s. At the time, landscape/environmental planners had to decide what to do without empirical evidence to support decisions. Therefore, there is a very strong heuristic basis for design and planning. Even today, much of a professional planner's and landscape architect's academic training addresses heuristic decision making through the planning process and the design process, processes that assist the professional deciding, "What to do?"

While planning began with a primarily physical planning approach, economic, social, and other forms of planning developed resulting in a diversified profession. Concurrently, science has rapidly advanced, especially during the last 30 years, offering the landscape planning scholar and practitioner a tremendous amount of potential analytic support and insight. Before that time, science was still exploring the formative development of analytic techniques and describing fundamental phenomena in the biosphere, and science had relatively little to contribute to such issues as "How should we plan, design, and manage the biosphere?" However, predictive methods in areas such as visual quality (Burley 1997), habitat design (Burley 1996), soil productivity equations (Burley 1999), and other environmental quality indicators have provided insight into the effects of spatial treatments pertinent to planning, design, and landscape management. The development of vegetation productivity equations to assess the effects of soil profile treatments upon vegetation is a recent example of this trend. Consequently, empirically based, scientifically assisted environmental planning has developed to the stage where potentially habitat models might assist the planner and designer to understand the impacts of various spatial treatments.

<u>Habitat Models</u>

A description concerning the origin of habitat suitability models and equation typologies was reported by Burley (1989a and 1989b) and presented by Verner *et al.* (1986). Essentially, habitat suitability models examine wildlife resource attributes such as cover, food, and reproductive environment which comprise the habitat. Each attribute may have one or more variables that mathematically represent the suitability of a resource attribute for a wildlife type. A collection of variables combined into an equation represents a wildlife type specific Habitat Suitability Index (HSI). By applying the model (equation), an investigator can estimate the suitability of a landscape for a particular wildlife type in a process called Habitat Evaluation Procedures (HEP), as illustrated by Burley (1996). The HSI models were originally developed for manual calculation; however, the HSI models were then developed in a micro-computer software program. Presently investigators are attempting to verify models and extend the utility of the models (Clark 2001, Loukmas and Halbrook 2001, Baumeister 1999, Kliskey *et al.* 1999, Roloff and Kernohan 1999, Gibbs 1997, Negri 1995). HSI models can be combined in multi-model investigations to examine a variety of proposed habitat management alternatives (Burley *et al.* 1988 and Westman 1985). Habitat modeling may become an important landscape assessment technique available to landscape planning and site design investigators as a tool to understand the impacts of site modifications and to optimize the site resources available to the designer to accomplish a variety of program objectives. However, there are limitations to the models. While habitat models may represent the state-of-the-art in predicting wildlife responses to habitat conditions, most of these models are heuristic, expertly derived equations with little field evaluation. Some of the models may only loosely represent wildlife habitat response to spatial treatments (Bender *et al.* 1996). In the wildlife habitat modeling sciences there is still much to learn and develop. Even though many of the models are over 20 years old, much testing, refining, and evaluation work needs to be accomplished. In conversations with numerous habitat modelers, the science of habitat modeling seems to be only slowly adopted or recognized by some wildlife and fisheries biologists.

This study advances an understanding of habitat modeling in surface mine applications in two ways. First, the study attempts to examine a statistical regression link between observed wildlife and ten habitat models for a specific study area. If there is a statistical link, then second, the models could be applied to a variety of landscape treatments to assess the second area of interest, the evaluation of surface mine treatments. Are any of the landscape treatments in the study areas significantly different across the multiplicity of wildlife types?

Study Area And Methods

The study area is in Colorado on a site owned by Colorado State University. The methodology employed incorporates landscape classification, wildlife observations, equation calculations, regression methods, and non-parametric analysis of variance.

Northern Colorado Nature Center

The site is at the location of a sand and gravel mine with sequential mining and reclamation starting in the late 1970s, providing habitat on the site during mining. Back in the 1960s, the descendants of a high plains pioneer farmer named Charles Rigden donated over 80 acres of land along the Cache la Poudre River, southeast of downtown Fort Collins, Colorado to Colorado State University. In time, the site was known as the Northern Colorado Nature Center, where students from Colorado State University conducted environmental studies, school children learned about the environment, and individuals walked along the trails.

During the 1980s, Dr. Howard Alden, a professor in Recreation Resources in the College of Natural Resources at Colorado State University worked with some landscape architecture students and identified 10 cover types across this study area (Figure 1). Some of the site had been mined and reclaimed, some areas would not be mined, and some areas remained to be mined and reclaimed. They identified a floodplain forest with 76-100% canopy comprised of plants such as narrow-leaved cottonwood [*Populus angustifolia*], chokecherry [*Prunus virginiana*], and boxelder [*Acer negundo*]. In addition there were two other somewhat forested to savanna types with 51-75% canopy and 26-50% canopy (Figure 2). They noted a grassland/urban savanna complex comprised of a building, mowed grasses, and ornamental shrubs. On the site were areas of exposed substrate, primarily consisting of cobbles, gravel, and course sands (Figure3). There were stands of saplings and stands of seedlings (Figure 3), with plains cottonwood [*Populus sargentii*] and the invasive and exotic salt cedar [*Tamarix pentandra*]. While the whole site, except for the building could be flooded, there were three predominantly wetland cover types, divided into shallow water/mudflats, water deeper than 2', and river (Figures 4 and 5). It was this landscape that was examined in the study described in this paper.

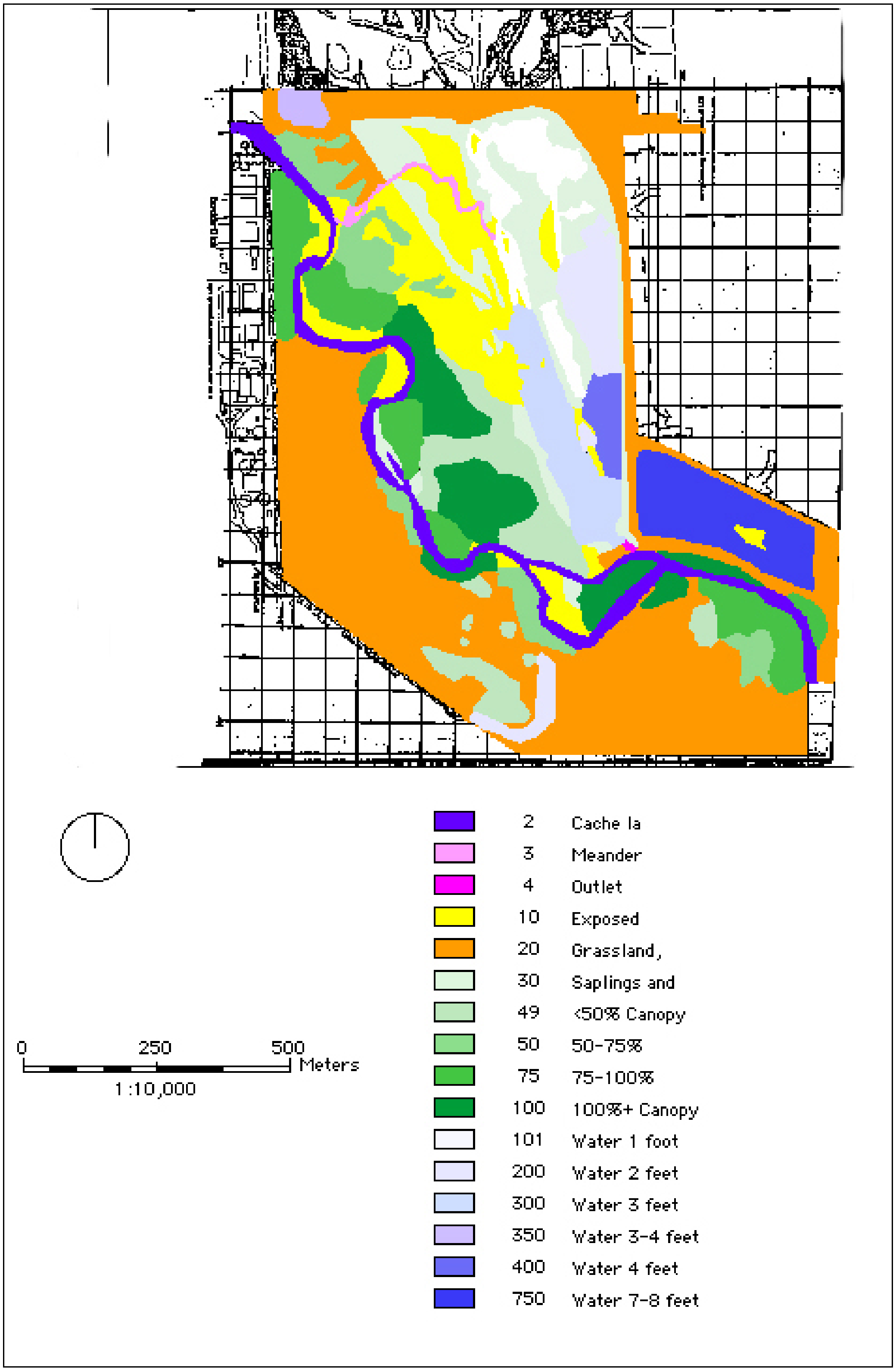

Figure 1. This map illustrates the composition of the landscape during field observations.

Figure 2. This photograph illustrates the vegetation of the canopy areas. This area was not mined for sand and gravel.

Figure 3. This photograph illustrates examples of exposed substrate, seedlings, and saplings. This area was mined for sand and gravel.

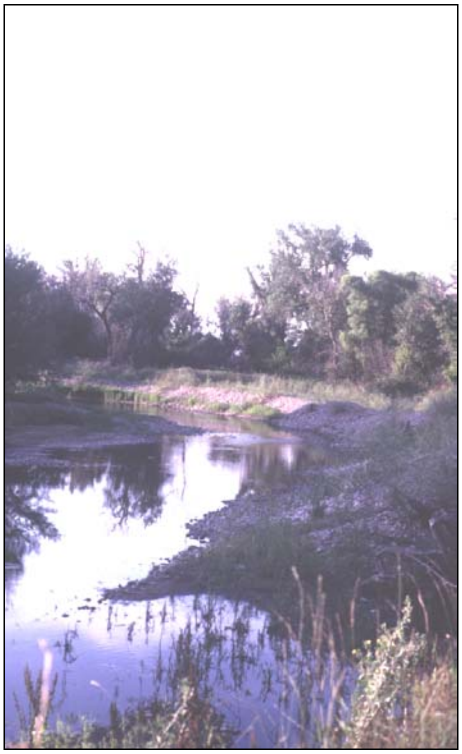

Figure 4. This photograph shows the Cache la Poudre River on the site during summer. This area was not mined for sand and gravel.

Figure 5. This photograph illustrates one of the wetlands created by surface mining.

After the classification study, the study area was combined with more land to form a block about 212 acres in size and is now called the Colorado Environmental Learning Center. The center is supported by student fees, and in 1993 Coors Brewing Company donated $500,000 for the construction of an environmental education building.

Wildlife Types

In 1989 and 1990, a graduate student (Matt Chew) working for Howard Alden, surveyed the site for one year at monthly intervals across the 10 cover types recording the number of birds, reptiles, amphibians, and mammals that he observed. The animals were typical for the floodplain area, comprised mostly of songbirds, waterfowl, and small mammals. Ten of the wildlife types observed had habitat models: tree squirrels [*Sciurus* sp.], downy woodpecker [*Dendrocopus pubescens*], black-capped chickadee [*Parus atricapillus*], Eastern cottontail [*Sylvilagus floridanus*], snapping turtle [*Chelydra serpentina*], great blue heron [*Ardea herodias*], Western grebe *[Aechmophorus occidentalis*], red-winged blackbird [*Agelaius phoeniceus*], belted kingfisher [*Ceryle alcyon*], and American coot [*Fulica americana*]). These ten wildlife types monthly observed across the 10 cover types, formed the study units for this investigation.

Statistical Methods

Two statistical approaches were employed in this investigation. First, I wanted to test to see if the predicted habitat model scores for the 10 wildlife types were related to the observed wildlife. If there was no relationship, then the models could not be used for predicting wildlife habitat across landscape treatments. I used a simple regression approach to see if the models and observed wildlife were linearly related.

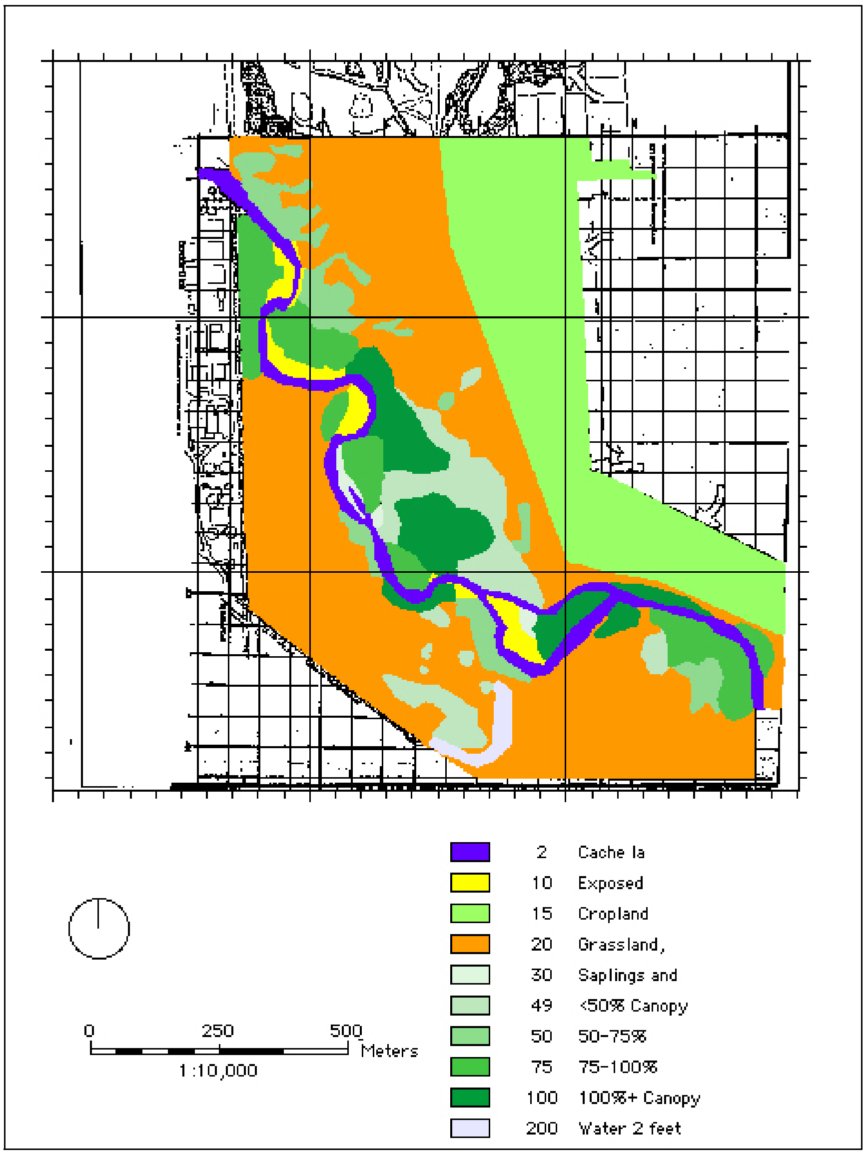

Figure 6. A map of the 1975 pre-mining cover type spatial configuration.

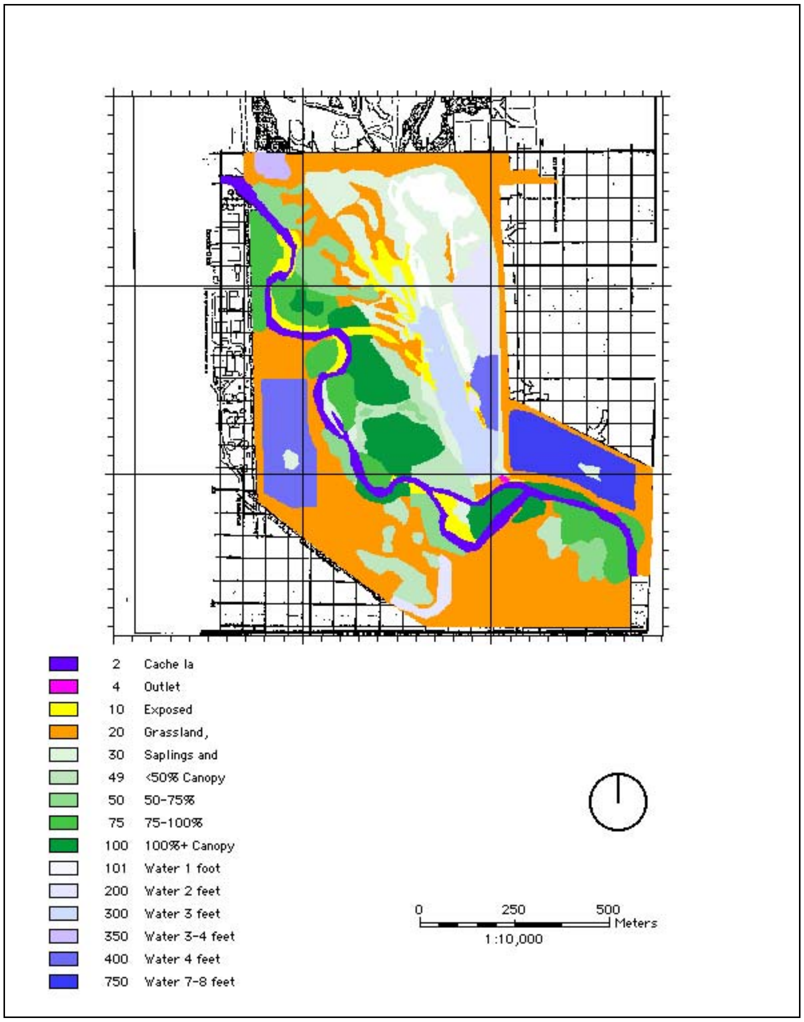

Figure 7. A map of the proposed 2036 spatial configuration.

Second, if the models and observed wildlife were statistically related (a significant regression with a $p<0.01$ explaining some portion of the variance), then I would apply the models to predicting the habitat suitability (blocks) of various landscape treatments for the years 1975 (pre-mine, Figure 6), 1977, 1979, 1981, 1986 (Figure 1), 1996, and 2036 (post-mining, Figure 7). I would use the Friedman two-way analysis of variance test (Daniel 1978) to see if any of the years were significantly different than any of the other years across the ten wildlife types. The cover types for these various treatments were determined by mapping the configuration of cover types based upon black and white aerial photographs for the assorted years. If the test revealed that at least one treatment was significantly different, then the Friedman multiple comparison test would be conducted to see which treatments were significantly different. Treatments that were significantly different can be examined for their spatial contents to assess their specific differences. However, since the reclamation that occurred in the site was sequential, treatments that are not significantly different might suggest that the sequential mining facilitated useful wildlife habitat as the mining and reclamation progress.

Results

The main effects model habitat score was a highly significant predictor ($p \leq 0.0001$) of observed wildlife occurrence, but explained only 32 percent of the variance in the data (Table 1). All of the regressors in the best equation were significant ($p \leq 0.05$). In examining various versions of a predictive model, the habitat score squared (HIS*HIS) did not render all regressors in the equation significant ($p \leq 0.05$).

Table 1. Results for the best selected regression equation to predict observed wildlife occurrence.

N: 82 Multiple R: 0.0573 Squared Multiple R: 0.328 Adjusted Squared Multiple R: 0.32
Standard Error of estimate: 0.857

Variable	Coefficient	Std Error	Std Coef	Tol	T	P(2 Tail)
Constant	-0.233	0.105	0.000	.	-2.214	0.030
HSI	2.422	0.387	0.573	1.000	6.253	0.000

Source	Sum-of-Squares	DF	Mean-Square	F-Ratio	P
Regression	28.747	1	28.747	39.105	0.000
Residual	58.810	80	0.735		

Since the predicted habitat score was a significant observed wildlife regressor, the seven treatments (k) across the ten wildlife types (b) were examined with the Friedman's two-way analysis of variance test. The test revealed that none of the treatments were significantly different ($p \leq 0.05$). The test revealed a Chi-square score of 4.38. For a Chi-square with 6 degrees of freedom and a p=0.05, the value is 12.592. Since 5.904 is less than 12.592, there is not enough evidence to say that the treatments are different. When the treatments are not different, there is no need to conduct the Friedman's multiple comparison test.

Table 2. Rankings of wildlife blocks (b) across year treatments (k).

Year/Wildlife	1975	1977	1979	1981	1986	1996	2036
Coot	6.5	6.5	4.5	4.5	3	1	2
Kingfisher	6.5	6.5	4.5	4.5	3	1	2
Chickadee	4	2	3	6	5	7	1
Woodpecker	1	2	3	4	5	7	6
Heron	7	6	5	4	3	2	1
Cottontail	4	5	1	2	7	3	6
Turtle	6.5	6.5	5	4	3	1	2
Squirrel	3	2	4	5	6	7	1
Blackbird	1	5	6.5	6.5	3	4	2
Grebe	4	4	4	4	4	4	4
Sum	43.5	45.5	40.5	44.5	42	37	27
Squared	1892.25	2070.25	1640.25	1980.25	1764	1369	729

Discussion

At the time they were developed, the expert derived habitat models were thought to be the state-of-the-art concerning what was known about wildlife habitat and predicting the suitability of wildlife habitat. However, as others have observed, some of the models do not explain much of the variance in wildlife occurrence. While the models appear to be significant in predicting some aspect of wildlife habitat, the models seem to be missing important factors in explaining the habitat needs of wildlife. Since these models were derived by examining the literature and then constructing equations to reflect this knowledge, the results suggest that possibly the equation construction method and the actual knowledge concerning the parameters governing various wildlife types may demand more scrutiny and extensive investigation. At the same time, it may be possible to state that when reconstructing wildlife habitat, the factors expressed in the equations are statistically definitive ($p \leq 0.001$), but they represent only a 30 percent accuracy rate, still leaving much to chance or factors we have not identified or do not yet understand.

When the seven treatments are examined across all ten wildlife types by applying the models, it is interesting to note the lack of differences in the overall habitat quality. No treatment is significantly better than any other treatment. For designers and planners, this may be disappointing, because often designers and planners will state that they can make the post-mining landscape better than the pre-mining landscape. And yes, the post-mining landscape does have a better score (lower total scores in Table 2 are better than higher scores), but not statistically better. However, upon reflection, this site may have some key features that influence the results. First, surface mining was accomplished in progressive stages, so the site was disturbed and reclaimed in progressive stages. Therefore, while some portion of the site may be disturbed, there was ample area to contain suitable wildlife habitat during all phases of the operations. Second, much of the site that was mined was not substantial wildlife habitat for the wildlife types studied. Disturbance of these poor habitat sites did not greatly affect the habitat scores. Third, the study was focused upon wildlife types that had habitat models. The availability of models was not random and may not reflect the distribution of all wildlife types available. It would be much better in an experimental design to have many wildlife models distributed across all wildlife types and then to randomly select wildlife models to use in the study. The approach applied in this study limits the generality of the results, confining the results to only the wildlife types studied within the high plains portion of the Cache la Poudre River. Finally, the study did not employ fish habitat models because fish were not sampled in the initial wildlife observation and occurrence study and so the fish models could not be corroborated.

Conclusions

Based on the results of this study, there is still more than 60 percent of the variance in the occurrence of wildlife types that needs explanation. Statistically predictive knowledge about wildlife habitat and wildlife needs much refinement. This investigation quantitatively illustrates that surface mining does not have to be destructive to the wildlife types studied, that the wildlife types studied can coexist with progressive mining and reclamation, and that potentially wildlife habitat can be sustained from pre-mining through post-mining conditions, as the pre-mining, mining, and post-mining scores are not significantly different. In addition, from the small amount of insight that habitat models may render, it appears that with an objective to manage for multiple wildlife types over a site, it may not be easy to develop a post-mining condition that is truly better for all wildlife types.

The tools of wildlife habitat assessment seem to be quite weak. Models need to studied, refuted, refined/corroborated, improved, and strengthened. While landscape planning and design has moved from the purely heuristic approach of the 1850s to the more informed approach of 2003, wildlife habitat planning, design, and management, especially for assessing surface mine treatments, is still in formative stages. Even though the models and ideas inherent in these equations are approaching 30 years in existence, progress seems slow and there is still much to learn and discover.

Acknowledgements

The author would like to thank Howard Alden and Matt Chew for their assistance and commitment to understanding and interpreting the environment.

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