AN ABSTRACT OF THE THESIS OF

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Models that assess the risk to biodiversity from landscape change can help communities prioritize planning decisions. Accurate representation of the ecology and life history traits of species is necessary. This study introduces the use of habitat quality in a biodiversity risk model to determine the significance of habitat quality when predicting risks to biodiversity due to landscape change. The difference between residential and forest habitats in terms of habitat quality for breeding birds was used to test the significance of habitat quality to the risk model. Relative habitat quality was estimated from population densities for 62 bird species associated with both forest and residential habitats. The effect of habitat quality was tested using two possible future landscapes: Buildout and Spine. Predicted risk for the 62 bird species due to landscape change increased by 74% in the Buildout Landscape and 31% in the Spine Landscape when habitat quality was considered. The life history traits of species most at risk were compared to the traits of species that benefited from the landscape change. Life history traits considered included foraging strategy, nest type and placement, migratory status, and area sensitivity. Species at high risk included ground nesters, foliage and tree trunk gleaners, neotropical migrants, and area sensitive species.

Habitat Quality and Assessing Risks to Avian Biodiversity

by

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Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Mary J. Barczak, Author

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HABITAT QUALITY AND ASSESSING RISKS TO AVIAN BIODIVERSITY

1.0 INTRODUCTION

As the human population increases, natural landscapes are increasingly altered to serve as human habitat. Landscape changes can result in significant loss of natural habitat for animal and plant species. We have the ability, with planned development, to design human-altered landscapes in various manners. One option is to plan human-altered landscapes with the needs of both wildlife and people in mind. Some conservationists have argued that it is necessary to conserve many plant and animal species within the developed landscape, in addition to relying on protected areas for species preservation (Western 1989, Soule 1991). Because protected areas such as parks and reserves cover only a small fraction of the terrestrial surface, they are unlikely to conserve thousands of species over the long-term (Western 1989, Soule 1991). It is more realistic to assume that if many species are to continue to exist in human-dominated landscapes, they will have to exist in the same area with humans. For example, Hansen et al. (1995) investigated how commodity forests can be managed to provide habitat for conserving biodiversity as well as produce wood resources. Soule (1991) claimed that the preservation of biodiversity will depend on multiple tactics, one of which is the use of agroecosystems, which provide food crops and some habitat for wildlife species. These studies emphasize a broader view of conservation where wildlife and humans use the same landscapes (Western 1989).

Models that predict the effect of landscape change on biodiversity can help land managers and planners make decisions about which landscape characteristics to prioritize. A method of assessing risks to biodiversity from landscape change was developed by White et al. (submitted) for Monroe County, Pennsylvania. This method used species-habitat associations, species area requirements, a habitat map of the present landscape, and habitat maps of six alternative future landscapes to assess the relative risks to biodiversity of each alternative landscape when compared to the present landscape. This risk was measured in two ways: as change in habitat abundance and change in species richness.

The objective of the current study was to determine the degree to which incorporating differential habitat quality into a biodiversity risk model affects the predictions of the model. This research modified the model developed by White et al. (submitted), specifically the method of assessing changes in habitat abundance due to gains or losses of habitat area. The original model had a simplifying assumption that species inhabit all habitat types they are associated with at equal population densities. The current study examined whether this assumption resulted in a serious overestimation of potential habitat abundances for many species in the landscape. If serious overestimation of habitat abundances existed, it would result in an underestimation of the overall risk to biodiversity.

For this study, habitat quality was estimated from differential population densities by habitat type. A set of 62 avian species associated with both residential and forest habitats was used to examine the effect of differential habitat quality on the original model. Population densities for these 62 avian species in residential and forest habitat types were obtained from the scientific literature. The existence of a significant difference between population densities in residential and forest habitats was investigated. This difference was crucial for justifying the modification of the original model. Life history traits were also used to explore the common characteristics of species at risk due to the potential landscape changes. In particular, the study looked at foraging strategy, nest placement and type, migration habits, and breeding bird sensitivity to forest patch size.

Monroe County, PA, was chosen as a case study due to the availability of data for the area and its species, and because it is under high development pressure. The county is approximately 1580 square kilometers in size and contains the core of the Poconos region. This region is physically defined by the Pocono Plateau, an uplifted sedimentary basin characterized by lakes and forests. The rest of the county is made up of the Allegheny uplands and the ridge and valley region of Pennsylvania. The natural history of the Poconos region is described in Oplinger and Halma (1988), and the significance of the area for conservation is discussed in Smith and Richmond (1994). The Poconos region is a prominent recreation area for the nearby metropolitan areas. Recreational use and permanent residents have increased with the introduction of an interstate highway system in the 1960s and 1970s. Population growth predicted for the future portends potential loss of natural habitat due to increased human pressures (White et al. submitted).

A map of the existing habitats of Monroe County with 13 habitat categories was prepared by Smith and Richmond (1994) in conjunction with the Cornell Laboratory for Environmental Application of Remote Sensing. Figure 1 shows an aggregation of these habitat categories for the existing landscape, as well as two alternative versions of the landscape of Monroe County in the year 2020, prepared by the Harvard Graduate School of Design (Steinitz et al. 1994). Only two of six alternative future landscapes were used, Buildout and Spine, because they adequately represent the other landscapes, and they are sufficient to test the effect of differential habitat quality on the model. Of the six alternative landscapes, the two chosen for use in this study were very similar to two of the other landscapes. The remaining two landscapes were designed with

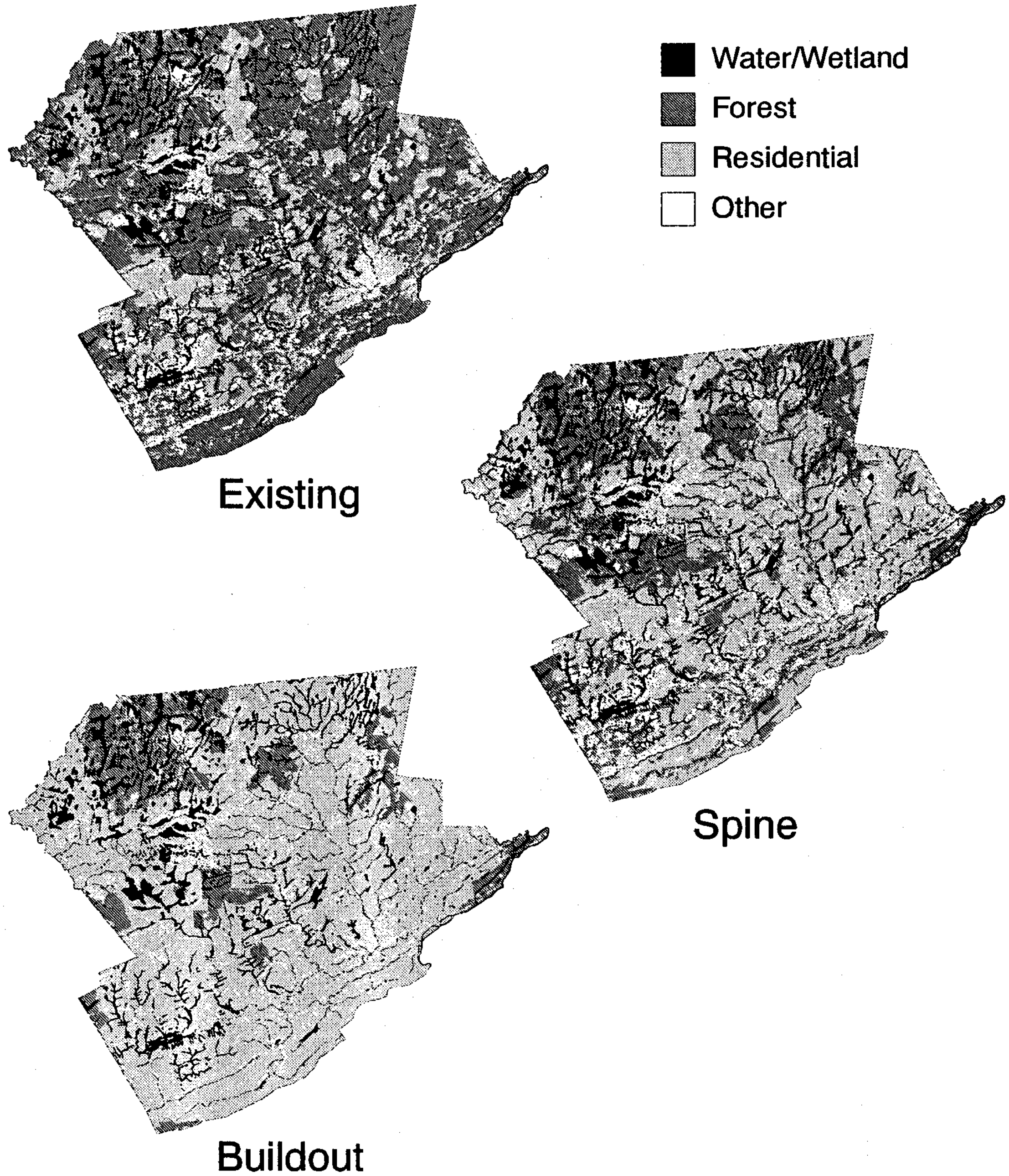

Figure 1. Existing and future landscapes, Monroe County, PA

Chapter two discusses the general importance of biodiversity, reasons for focusing on residential- and forest-dwelling avian species, prior studies of residential and forest avian communities, and the connection between population density and habitat quality. Chapter three describes the methods used to obtain the objectives of this study. The results are given and discussed in chapter four. Chapter five contains the conclusions.

2.0 BACKGROUND

2.1 IMPORTANCE OF BIODIVERSITY

Biodiversity, in particular the variety of plants and animals at the species level, is declining. This is cause for worldwide concern (Grumbine 1992). One of the largest factors involved in the degradation of the environment is the continual increase of the human population (Wilson 1988, Brussard 1991). As the human population increases, the demand for fuel, building materials, and agricultural land also increases and threatens biodiversity through the destruction of natural habitat (Norgaard 1988, Brussard 1991, Wilson 1988).

There are many reasons for people to be concerned with the loss of biodiversity. Biodiversity has worth to society that is most easily measured in its commodity form, such as in pharmaceutical products and food crops (Norton 1988, Brussard 1991). Many people value biodiversity for amenity and moral reasons (Norton 1988). A species has amenity value if its presence increases human enjoyment in a non-material way, such as the joy of viewing a soaring hawk. The moral value of species refers to the innate worth of species, which is not dependent on human use.

A fourth value of biodiversity is its contribution to ecosystem function. Human beings are linked with the diversity of organisms that play vital roles in ecosystem function (Ehrlich 1988, Norton 1988, Franklin 1993). Plants and animals are involved in such functions as the exchange of gases in the atmosphere, providing high quality water sources, pollination of necessary food crops, waste detoxification, providing fish habitat, and pest control (Ehrlich 1988, Brussard 1991, Soule 1991). If enough diversity is lost, air pollution will increase, climates will become harsher, and crop yields will decline due to soil loss and uncontrolled pest populations (Ehrlich 1988).

Local extinction of certain organisms can impact society by impairing ecosystem function. When a population that fulfills a role in the ecological system is destroyed, that function may cease to be performed locally (Ehrlich 1988). In addition, more diverse communities are believed to be more resistant and resilient to disturbance. A study by Tilman and Downing (1994) of prairie grassland plots showed that the more diverse plant communities had higher resistance and resiliency during drought as measured by percent vegetation cover. Thus, diversity may enable local ecosystems to escape the worst effects of disturbances.

2.2 WHY USE RESIDENTIAL- AND FOREST-DWELLING SPECIES?

Vertebrate species can be useful indicators of ecosystem health. Other indicators of ecosystem health, such as stability or resiliency, are more difficult to measure (Franklin 1993). This paper focused on avian species because they compose a large part of vertebrate species diversity. Out of 41,000 vertebrate species, approximately 9,000 are avian species (Wilson 1988). In addition, many people value seeing or hearing birds in residential areas, and their presence can enhance the livability of urban and suburban areas (Dagg 1970 as cited in Williamson and DeGraaf 1980). Birds are also good subjects for study due to their conspicuous nature (DeGraaf and Wentworth 1981) and the availability of life history data. During the breeding season, censuses of bird species are relatively easily obtained from the songs of singing males (DeGraaf and Wentworth 1981). Due to the diurnal habits of most birds, they can also be identified by sight.

The difference in habitat quality for birds, specifically in residential and forest habitats, was investigated because population density data for these habitats are available. By looking at this subset of birds, the significance of habitat quality to biodiversity risk modeling could be tested. In addition, the original analysis by White et al. (submitted) indicated that species found in both residential and forest habitats may merit further research. The original study showed that forest habitat was one of the most seriously affected habitat types in the study area. However, many species associated with forest habitats were not predicted to be at risk because they were also associated with residential habitat, which increased by 200% in some landscapes. Forest area decreased by 85% in some of the alternative future landscapes when compared to the existing landscape. In the existing landscape of Monroe County, forest habitats dominate the area (approximately 860 square kilometers) and residential areas are relatively small (380 square kilometers). In the Buildout landscape, the ratio of forest to residential area is reversed (forest habitats cover 180 square kilometers and residential areas cover 1150 square kilometers). In the Spine landscape, this change in forest and residential area is less pronounced (forest habitat covers 475 square kilometers and residential habitat covers 740 square kilometers). If the densities of bird species associated with both residential and forest habitats were lower in residential habitats than in forest habitats, the analysis was underestimating the true risk to their habitat abundance. Habitat abundance was originally calculated with the assumption that bird densities were equal in all habitat types (i.e., no difference in habitat quality was considered).

2.3 PRIOR STUDIES ON RESIDENTIAL AND FOREST AVIAN COMMUNITIES

The following discussion summarizes some studies of residential and forest avian communities and illustrates why a difference in residential and forest population densities was suspected. Studies of avian communities in human residential areas have looked at the total density of all species, species richness, and the effects of vegetation structure. The total density of birds in residential areas is, generally, higher than in natural habitats (Mills et al. 1989, Beissinger and Osborne 1982, Lancaster and Rees 1979). However, species richness is lower in residential areas, as a small number of species dominate the residential area (Mills et al. 1989, Beissinger and Osborne 1982, Lancaster and Rees 1979). Environmental factors in residential areas favor seed-eating birds and ground-feeders (Lancaster and Rees 1979). These species, such as European Starling (*Sturnus vulgaris*) and House Sparrow (*Passer domesticus*), are able to capitalize on the resources available in human habitats. They expand in numbers to dominate the community, eventually becoming pests (Lancaster and Rees 1979, Beissinger and Osborne 1982, Mooney and Drake 1986 cited in Hansen et al. 1992).

Foliage volume in residential areas is less than in natural habitats. This may limit the food resources, nest placement, and ability to avoid predators for some species (Beissinger and Osborne 1982). Areas of decreased shrub layers and decreased canopy area do not support colonization by low-dwelling species or foraging by many insectivorous species which feed by gleaning from plant surfaces. Often vegetation in residential areas is comprised of ornamental, fruit-bearing species which favor colonization by omnivorous or seed-eating birds. These resources do not encourage insectivorous birds (Beissinger and Osborne 1982). Even residential areas of increased vegetation volume do not provide forest insectivores with an adequate substitute for forest habitats (DeGraaf and Wentworth 1986).

Other characteristics of residential areas that influence the composition of the bird community are automobile traffic, noise and air pollution, extreme vegetation fragmentation, elevated predation by species such as cats, opossums, jays, raccoons, and crows (Beissinger and Osborne 1982, Goldstein et al. 1986), and increased nest parasitism (Terborgh 1992). These factors are usually not found or are less intense in natural habitats, and these disturbances may suppress the reproductive success of some species (Beissinger and Osborne 1982, Bosakowski et al. 1993, Goldstein et al. 1986). Though it is difficult to prove the effects of such disturbances, Emlen (1974) provided some evidence that human disturbance played a role in the elimination of two ground-dwelling birds in his study area. Beissinger and Osborne (1982) found that ground-foraging species and those that nest above ground were more likely to adapt to human disturbances. Of 21 species found in a residential study area, 16 were arboreal nesters, and those with the highest densities (Common Grackle, *Quiscalus quiscala*; Cardinal, *Cardinalis cardinalis*; American Robin, *Turdus migratorius*) fed on lawns. Those that fed on plant surfaces were able to colonize in small numbers (Beissinger and Osborne 1982). Reijnen et al. (1995) found that 60% of the breeding bird species analyzed in their study showed reductions in density of 20% to 98% when adjacent to roads.

A study by Walcott (1974) revealed how the composition of an avian community in residential habitat was influenced by gradual urbanization in Cambridge, MA, from 1860-1964. In particular, Walcott (1974) addressed the ratio of insectivorous migratory species to omnivorous or seed-eating permanent residents (Walcott 1974). The composition of the avian community shifted from one where most species were migratory and few were permanent residents to one where the majority of species were permanent residents. Insectivorous migratory species decreased from 25 species to 3 species over the time period (Walcott 1974). In addition, the number of non-nesting (transient) species in the study area increased until, by 1964, they outnumbered the nesting species.

In a study of bird communities in Tucson, AZ, 66% of all individual birds and 66% of the biomass belonged to three species that were alien to the natural habitat of the area (Inca Dove, *Columbina inca*; House Sparrow, European Starling) (Emlen 1974).

These studies provide evidence that residential areas favor certain avian species. Some species adapt so well to the conditions found there that they dominate the resources in the residential avian community, reducing species richness and abundance below the level found in surrounding natural habitats. Although an individual of a species that is rarely found in residential areas can sometimes be found breeding there, the species is not well-adapted to the conditions of residential habitats. The fact that these species occur in much higher densities in their natural habitats indicates that natural and residential habitat are not equal in quality for these species.

Much research on the diversity and composition of avian communities in forest habitats has focused on the importance of forest fragmentation, forest size, vegetation structure, and migratory habits of avian species. Forest fragmentation is hypothesized to be the cause of population decline of some species of forest birds. Forest fragmentation decreases the area of forest habitat and increases the amount of forest edge, which fosters nest parasitism (Robbins et al. 1989, Robinson et al 1995). Nest parasitism is one possible cause of population declines. Forest fragmentation reduces forest patch size. Studies have shown that avian species richness and composition are related to forest patch size (Whitcomb et al. 1981, Freemark and Merriam 1986, Robbins et al. 1989). Increases in forest patch size are correlated with increases in the number of forest interior species and resident species (Freemark and Merriam 1986). Habitat preference and migratory habits of species can be indicators of sensitivity to fragmentation. Habitat preference here refers to the preference of species for forest edge habitats or forest interior habitats. Whitcomb et al. (1981) found that the number of forest edge species was negatively correlated with forest tract size, and the number of forest interior species was positively correlated with forest tract size. Small forests (<15 ha) were dominated by edge species or permanent residents. Robbins et al. (1989) conducted research in the Middle Atlantic states and discovered that out of 75 forest nesting species, the abundances of 38 species were significantly related to forest size. These relationships were positive or negative, depending on the species.

These studies of forest size and fragmentation indicate that some forest bird species, based on their migratory habits and preference for interior habitats, are sensitive to the amount of forest available. These species are not likely to breed in residential areas.

Features of the physical environmental may reflect the suitability of a site for avian reproduction and survival. Increases in the structural heterogeneity of forest communities are believed to provide greater avian niche diversity (MacArthur and MacArthur 1961). Vegetation structure has also been shown to have a significant effect on species richness and density of breeding birds (Swift et al. 1984).

DesGranges (1980) found that the composition of forest avian communities is influenced by plant physiognomy (structure and outer appearance) more than by plant species composition. As ecological succession progresses, the physiognomic diversity of forest stands increases, plant communities become more stable, and there is greater diversity of feeding niches. DesGranges (1980) also investigated the relationship between the structure of the environment and species composition. He found that insectivorous species that feed on tree trunks or in flight were most common in deciduous stands. Insectivorous species that feed in the canopy and omnivorous species were most common in the coniferous forest stands. The structure of the environment was given as a possible explanation for the correlation between habitat type and the foraging strategy of the most abundant species. For instance, species that feed in flight can maneuver most easily in deciduous forests where the trees are tall and well-spaced, and so they are most common in deciduous environments (DesGranges 1980). If the abundance of bird species is significantly influenced by the structures of different *forest* environments, the very different attributes of residential environments can be expected to influence their abundance in residential environments relative to forest environments.

Neotropical migrants have warranted close attention from avian ecologists in recent years due to declines in the populations of some species. Many neotropical migrants are forest-dwelling species. The behavior of neotropical migrants may limit their ability to adapt to disturbed or human-impacted areas. Eastern neotropical migrants are open-nesters and may nest on or close to the ground, which increases their vulnerability to predator species. They also appear to be 'behaviorally rigid' as they are unable to use disturbed, patchy habitat (Whitcomb et al. 1981). Short distance migrants and permanent residents, however, are able to capitalize on disturbed environments such as residential areas. Neotropical migrants may be more seriously affected by nest parasitism than other species because they are short-term residents of breeding grounds; thus they have less time to nest successfully (Robbins et al. 1989).

2.4 POPULATION DENSITY AND HABITAT QUALITY

This study used population density as an estimate of habitat quality. Habitat quality is the ability of an environment to provide conditions needed for survival, reproduction, and population persistence (Block and Brennan 1993). While habitat quality is related to factors such as survival rate and reproductive rate (Van Horne 1983), population density is also an important factor when considering habitat quality for long-term maintenance of a species. Use of population density has been challenged as the sole indicator of breeding success or habitat quality. Two studies found that breeding success may be higher in areas of lower population density (Van Horne 1983, Vickery et al. 1992). However, these studies focused on habitat quality comparisons between relatively similar *natural* habitat types. Existing literature indicates that natural and residential habitats are significantly different habitat types, such that the population densities in each differs to the extent that density is a reasonable estimate of habitat quality. In addition, survival and reproductive rates were not available by habitat type for many species in this study. While this information (along with density data) would make comparison of habitat quality more accurate, the only data available by habitat type for all the species considered in the current study were density data.

For any species that occurs in more than one habitat, birth and death rates will differ by habitat type (Pulliam 1988). Sink habitats are habitats in which a species' reproductive rate does not equal mortality rates. Many individuals of a species may occur in sink habitats. These populations are maintained by individuals that emigrate from source habitats (Pulliam 1988). Inspection of densities of avian species in residential areas is especially important if these areas are population sinks, where population loss is greater than the reproduction rate. Populations in residential areas would thus depend on the excess reproduction over mortality from forest habitats to maintain the population over the long-term (Pulliam and Danielson 1991).

The source/sink issue is not considered in this comparison of residential and forest habitats. Such a comparison would require data on the birth, death, emigration, immigration, and reproductive rates by habitat type. As stated earlier, these data are not available for most species. This study, however, points out the need for collection of such data in order to improve our ability to model population viability in human-impacted landscapes.

There are two limitations concerning the density data used in this study. First, density estimates have uneven quality due to the different census methods employed in the various studies referenced in this paper. Second, population density is ecologically influenced by several factors besides habitat type: interspecific interactions, regional population levels, and the habitat distribution in the region (Carrascal and Telleria 1991).

3.0 METHODS

3.1 DATA GATHERING

A list of 62 bird species with habitat associations that included both residential and forest habitat types (hereafter referred to as RF-species) was compiled from the original list of 147 native breeding bird species found in Monroe County, Pennsylvania (Smith and Richmond 1994, White et al. submitted). Introduced species (e.g., European Starling) were excluded from the analysis. The list of RF-species is given in Appendix A, and scientific names are given in Appendix B.

The literature search for the current study produced several articles containing population density estimates for these species in both residential and forest habitats (see Appendix A for complete list of sources). Data from publications reporting territorial bird density, nest density, or censuses of non-territorial breeding birds were used whenever possible. Data from areas typical of the Northeastern United States were used in this study. Noon et al. (1980) compared bird and habitat data from a wide geographic range in the Eastern United States and Canada. This study supported the use of bird habitat data from areas included in their breeding range, when data from the local study site are not available.

Residential bird population densities were taken from several articles on residential bird communities (see Appendix A for list of sources). Densities were taken from study areas located in human residential areas of medium density (one housing unit per 0.10 - 1.00 ha, or 0.25 - 2.50 acres). This human population density corresponded with the predicted human residential densities in the future landscapes for Monroe County (Steinitz et al. 1994). The bird density figures were recorded for each species from each study, and the median of these figures was used as an estimate of residential density for each species.

Due to the vast amount of data available on avian densities in forest habitats, a compilation source by DeGraaf and Rudis (1986) provided the vast majority of data for densities of forest birds. Appendix A lists the other sources used to provide densities of forest birds not found in the study by DeGraaf and Rudis (1986). Data from these sources were used to obtain median bird population density figures for each species in forest habitat types. Population densities from any forest types found in Monroe County were used to estimate a general forest habitat population density for all RF-species.

A literature search provided descriptions of the habitat requirements of those species for which no residential densities could be found. This information was used to refine species-habitat associations. If the literature indicated that a species very rarely inhabited residential areas, presence in residential habitats (1), as reported in Smith and Richmond (1994), was replaced with absence (0) in the habitat association matrix. The zero value more accurately reflected the extremely low density of these species in residential areas. If the literature did not indicate that residential habitat was unsuitable, residential density was given equal weight to forest density. The species for which residential density data were not available are indicated in Appendix B.

Residential population densities could not be found in the literature for 13 of 62 species coded to residential and forest habitats. Habitat needs for these 13 species were investigated and their habitat associations were reassessed using various sources.

Ten species have life history traits that most likely render residential areas unsuitable as breeding habitat. These life history traits, plus the absence of any report of these species in studies of residential bird communities, supported the assignment of zero to the residential column in the habitat matrix. While an occasional member of these species may be found in residential areas, their rarity led to the re-classification of residential areas as non-habitat. These ten species and a discussion of their relevant life history traits follow.

The Sharp-shinned Hawk's (*Accipiter striatus*) primary habitat is open coniferous forest. Recommended management practices for this species include protection of nesting areas from alterations or development, as well as the use of a buffer zone to protect nest sites from development (Jones 1979). Intensive agricultural practices have been reported as adverse to this hawk (Bent 1937). Since the Sharp-shinned Hawk is sensitive to human developments and activities, it is unlikely that it will inhabit residentially developed areas.

Cooper's Hawk (*Accipiter cooperii*) is normally found in riverine woodlands, woodlots, and open farm country. It nests in densely vegetated sites (Reynolds et al. 1982). Closed canopy is also required for nesting (LeGrand and Hamel 1980), and it hunts over open fields (Brown and Amadon 1968). Residential areas are typified by lawns and scattered trees, which do not provide dense vegetation for cover or open fields as a food source. Bosakowski et al. (1993) found that active nests of Cooper's Hawk were surrounded by an average of 87% forested habitat and 1.4% suburban habitat. This indicates the danger of assuming that homogeneous residential areas are habitat for this species due to an occasional observation of a hawk nest near a house. Cooper's Hawks select breeding habitat that averages 1 km in diameter in a forest habitat without a single house, providing strong indication that residential areas are not suitable habitat (Bosakowski et al. 1993).

The Red-tailed Hawk (*Buteo jamaicensis*) requires open woodland for perching and open country for hunting. The average suburban area may provide tall trees for perching, but not open fields for hunting. The number of hawks corresponds negatively to human population density (Brauning 1992). The density of human population and associated disturbances renders residential suburbs unsuitable to nesting Red-tailed Hawks.

The Great-horned Owl (*Bubo virginianus*) breeds mainly in wetlands, forests, or near agricultural lands. However, the owl's preference for breeding in large woodlots (over 10 acres in size) has been documented (Craighead and Craighead 1956). Large areas of continuous forest are rare in the typical residential area; thus residential areas are not supported as breeding habitat for Great-horned Owls in this paper.

The Black-billed Cuckoo (*Coccyzous erthyropthalmus*) is a secretive bird about which not much is known. It nests in forest habitats, specifically in the shrub layer (LeGrand and Hamel 1980). This species is not likely to be found in suburban areas (Brauning 1992), and it is typically found in forest stands greater than four acres in size (Forman et al. 1976). Due to this species' sensitivity to forest area and its preference for nesting in dense shrubs and thickets, residential areas are not suitable habitat for breeding. Suburban areas may have tree cover, but a dense shrub layer is usually lacking.

The Whip-poor-will (*Caprimulgus vociferus*) uses open deciduous forest or mixed forest with fields or other cleared areas. It is a ground-nesting bird that requires thick deciduous leaf-litter to nest (LeGrand and Hamel 1980). This species does not adapt well to human activities, as dogs and cats are serious threats to ground-nesting birds (Brauning 1992). Residential areas do not seem to provide suitable habitat for the Whip-poor-will.

The Bank Swallow (*Riparia riparia*) uses mainly riparian habitats as it nests in the vertical walls of stream banks. This species also nests in roadcuts and gravel pits. The Bank Swallow feeds along the riparian zone, in agricultural fields, or in grasslands

(DeGraaf et al. 1980). Residential areas have been reported as unacceptable to the species (Bergstrom 1951).

Residential areas are unsuitable to the Veery (*Catharus fuscescens*) due to its ground-nesting habits, which require dense undergrowth (DeGraaf et al. 1980). As cited above, suburban neighborhoods do not contain ample undergrowth, and they do support ample populations of dogs and cats which prey heavily on ground-nesters.

Both the White-eyed Vireo (*Vireo griseus*) and Yellow-throated Vireo (*Vireo flavifrons*) have been associated with suburban areas in past studies (Brauning 1992). However, the scientific literature on residential bird communities does not report the presence of either species. Increases in Brown-headed Cowbird (*Molothrus ater*) predation and insect spraying may account for the rarity of these two species in developed areas. The current study removed residential habitat from the list of suitable habitats for these two species based on their extreme rarity in these areas.

Three species, which did not have published residential densities, were given equal weight in both forest and residential areas. Although these species were not reported in studies of residential bird communities, their life history traits indicated a positive association with human developments. The Eastern Screech Owl (*Otus asio*) is known to breed in residential and urban areas (Terres 1980, Bohlen 1978, Bent 1938). The Common Nighthawk (*Chordeiles minor*) is also closely associated with residential areas (AOU 1983, Terres 1980, Bohlen 1978). The screech owl and nighthawk are both nocturnally active birds, thus they would not be commonly observed in most bird community studies carried out during the day. The Cliff Swallow (*Hirundo pyrrhonota*) was not reported in residential bird studies. This species commonly uses residential areas, croplands, and lakes, and the Cliff Swallow also frequents canals and reservoirs. The Cliff Swallow's preference for nesting in manmade structures (DeGraaf et al. 1980, Emlen 1952, Bent 1942) supports an equal weighting for residential habitat and forest habitat. The failure of the literature to report this species could be an artifact of the species' colonial nature. If the sampling scheme did not cover the area in which a colony was nesting, the species could easily be missed.

3.2 STATISTICAL ANALYSIS

A key question for this study was whether there existed a significant difference between residential and forest densities. Statistical tests can be used to test for differences in two populations. Since the data sets being compared were not normally distributed, a nonparametric test was chosen. Transformation of the data to a logarithmic scale did not yield a normal distribution. Nonparametric statistical procedures are useful in making inferences when the underlying assumptions of standard parametric tests are not met (Mendenhall et al. 1981). Thus, the Wilcoxon signed-rank test for a paired experiment was used to test the hypothesis that the distributions of the residential and forest densities were the same versus the hypothesis that the distributions differed in location.

Under the null hypothesis of no difference between the distributions, the expected result is that half of the species have negative outcomes and the other half of the species have positive outcomes. Also, positive and negative differences of equal absolute magnitude should occur at equal probabilities (Mendenhall et al. 1981). Thus, when the absolute values of the differences were ranked, the sum of the ranks of the positive values should equal the sum of the ranks of the negative values. Sizable differences in the sums of the assigned ranks to positive and negative values would indicate a difference in the location of the distributions (Mendenhall et al. 1981).

3.3 BIODIVERSITY RISK ANALYSIS

3.3.1 INCORPORATING HABITAT QUALITY INTO THE MODEL

A ratio of the residential population density to forest population density was calculated. This ratio,

$$\frac{\text{residential population density}}{\text{forest population density}}$$

(hereafter referred to as the R:F ratio), indicated whether the habitat quality of residential habitat was higher or lower than forest habitat for each bird species.

A habitat matrix was used in this study to indicate the presence (1) or absence (0) of a species in each habitat type in Monroe County (see Appendix B). The R:F ratio was used to replace the '1' in the residential column of the habitat matrix, in order to weight the quality of residential habitat based on relative densities. If the ratio was greater than one, residential habitat was of greater quality for a species. If the ratio was less than one, forest habitat was of greater quality for a species. If the ratio was equal to one, the species did not encounter a difference in habitat quality between residential and forest habitats. The result was a habitat matrix that incorporated differential habitat quality of residential habitat compared to forest habitat.

3.3.2 RISK ANALYSIS OF THE RF-SPECIES INCORPORATING HABITAT QUALITY

The habitat abundance for a species is the amount of land area available in that species' associated habitats. Total habitat abundance for each RF-species was used to calculate the amount of risk to the whole group of RF-species in the future landscapes due to landscape change.

The habitat abundances were calculated for the present landscape of Monroe County, PA, by using matrix multiplication in S-PLUS, a statistical and data analysis software program. The two matrices used were a matrix of the habitat types to which each species was coded (Appendix B) and a matrix of the amount of land presently available in each habitat type in the present landscape and the two alternative landscapes. The outcome of this multiplication was the amount of habitat available to each species in each landscape.

Comparison of habitat abundance in the future landscape to the present landscape, for each species, involved creating a ratio of the habitat abundances. This ratio:

$$\frac{\text{habitat abundance in future landscape}}{\text{habitat abundance in existing landscape}},$$

represented the proportion of habitat abundance available in the future landscape when compared to the habitat abundance in the existing landscape. A ratio of less than 1.0 occurred when a species experienced loss of habitat abundance in the future. A ratio of more than 1.0 indicated an increase in habitat abundance in the future.

Analyzing the risk to the group of RF-species in both of the future landscapes involved summary statistics of the proportions of habitat abundance in the future landscape relative to the present landscape for each RF-species. These proportions were transformed to the natural logarithm scale, in order to remove the skewness of the empirical distribution. The mean of the proportions was then determined. Next, the mean was back-transformed to the original scale. This resulting geometric mean was used as a measure of central tendency. This value represented the proportion of habitat available to all RF-species in the future landscape when compared to the present landscape. When subtracted from one, this value yielded the proportion of habitat abundance at risk in the future landscape. These algorithms are summarized in symbolic form in Figure 3. The predictions of the model incorporating habitat quality were then compared with the predictions of the original model.

Figure 3: Symbolic descriptions of algorithms for computing comparative risk scores for habitat abundance (White et al. submitted).

<u>Formulas</u>:

Habitat Abundances:

$$\forall_l \forall_s : \quad b_{l,s} = \Sigma_c \, a_{l,c} \cdot i_{c,s}$$

Proportion of Habitat Abundances at Risk:

$$\forall_f \forall_s : \quad p_{f,s} = b_{f,s} / b_{0,s}$$

$$\forall_f : \quad k_f = 1 - \exp(\text{mean}(\ln(\mathbf{p}_f)))$$

<u>Symbols</u>:

$\forall$	universal quantifier (i.e., for all elements...)
l	indexes all landscapes
0	indexes present landscape
f	indexes future landscapes ($l \neq 0$)
s	indexes all species (or classes of species)
c	indexes habitat categories
$i_{c,s}$	indicator variable for a species in a habitat category
$a_{l,c}$	area of a habitat category in a landscape
$b_{l,s}$	habitat abundance of a species in a landscape
$p_{f,s}$	proportion of a species' present habitat abundance in a future landscape
$\mathbf{p}_f$	vector of proportions of all species' present abundances in a future landscape
k_f	risk to habitat abundance in a future landscape
n_l	number of species in a landscape
exp	exponential function
mean	population mean
ln	natural logarithm

3.3.3 INFLUENCE OF HABITAT QUALITY ON RISK ANALYSIS OF ALL BIRD SPECIES AND ALL VERTEBRATE SPECIES IN MONROE COUNTY:

This study also investigated the influence of incorporating differential habitat quality for the set of RF-species on the outcome of risk analysis for all (147) bird species and all (231) vertebrate species in Monroe County. The outcomes of these analyses were compared with the risks calculated by the original model. The technique was the same as explained in section 3.3.2.

3.4 SPECIES RISK GROUPS AND LIFE HISTORY TRAITS

An exploratory analysis of the life history traits of RF-species and their risk status was conducted. Each species was placed in one of three risk groups. The assignment of species to a risk group was based on the ratio:

$$\frac{\text{future habitat abundance}}{\text{present habitat abundance}}$$

for each species. The following cutoff points for the three risk groups were subjectively determined. Those species with ratios of 0.00 to 0.50 were called *negatively impacted.* The reasoning for these cutoff points was that species that lost one half or more of their habitat abundance would experience a definite negative impact. Reduction of the habitat abundance for these species by one half or more would decrease the area available to support the population of that species in the county. The smaller the population size of any species, the more likely that a disturbance could cause local extinction of that species. Species with ratios from 0.50 to 1.10 were *minimally impacted.* These cutoff points were chosen in an effort to obtain a minimally impacted group. These are species that are affected by the landscape change, but not as severely as the negatively impacted group. They lose some of their habitat abundance, but not more than one half of it. The upper limit of 1.10 was chosen to separate this group from those species that experience a definite and larger increase in habitat abundance. An increase of 0.1 in habitat abundance was seen as virtually no impact due to landscape change. Species with ratios from 1.10 and above were *positively impacted* by landscape change. These species gained significant amounts of habitat due to landscape change.

The life history traits of each species were analyzed to determine if they could explain the species' risk status. The life history traits of foraging strategy, nest placement and type, migratory status, and sensitivity to forest patch size (also referred to as area sensitivity) were studied. These traits were obtained from published reports and are listed in Appendix C.

4.0 RESULTS

4.1 DATA GATHERED

The densities reported in scientific literature for RF-species in residential habitats were generally much lower (approximately 20 times lower on average) than the densities reported in forest habitats. The medians of reported densities can be found in Appendix A. Forty-three species had published densities that were considerably higher in forest habitats than in residential habitats. Six species had higher reported densities in residential areas than in forest habitats. Three species had no reported residential densities and were assigned equal weight to residential and forest habitats, based on descriptions of habitat associations. Ten more species had no reported residential densities and were re-assigned to only forest habitat, based on published habitat association data. The median of the forest densities was 11.29 birds per 40 hectares, and the median of the residential densities was 0.55 birds per 40 hectares.

The Wilcoxon signed-rank test for a paired experiment at a 95% confidence interval was used to compare the distribution of forest densities with the distribution of residential densities. This statistic showed a significant difference between residential and forest densities, which was critical to justify modifying the original model. There was very strong evidence that the locations of the distributions were significantly different in location ($Z = -5.47$, p-value < 0.01). This result allowed the rejection of the null hypothesis of no difference in the locations of the distributions. The Wilcoxon test clearly indicated that the residential densities for most RF-species were much lower than forest densities.

4.2 RISK TO BIODIVERSITY

4.2.1 BUILDOUT RISK

Incorporation of density-weighted habitat quality resulted in a quanitative change in the predictions of proportion of habitat abundance at risk for both landscapes and all three classes of species (RF-species, all bird species, all vertebrate species). See Figure 4. The original analysis showed a proportional *increase* of 0.12 in the habitat abundance for RF-species in the Buildout landscape, (which was -0.12 proportion at risk). When residential habitat quality was built into the habitat association matrix, the proportion of habitat abundance at risk was 0.62. The proportion at risk for all bird species was 0.39 in the original model; the proportion at risk with residential habitat quality factored in was 0.61. The original proportion at risk for all vertebrates in this landscape was 0.43; the proportion at risk using avian residential habitat quality increased to 0.57.

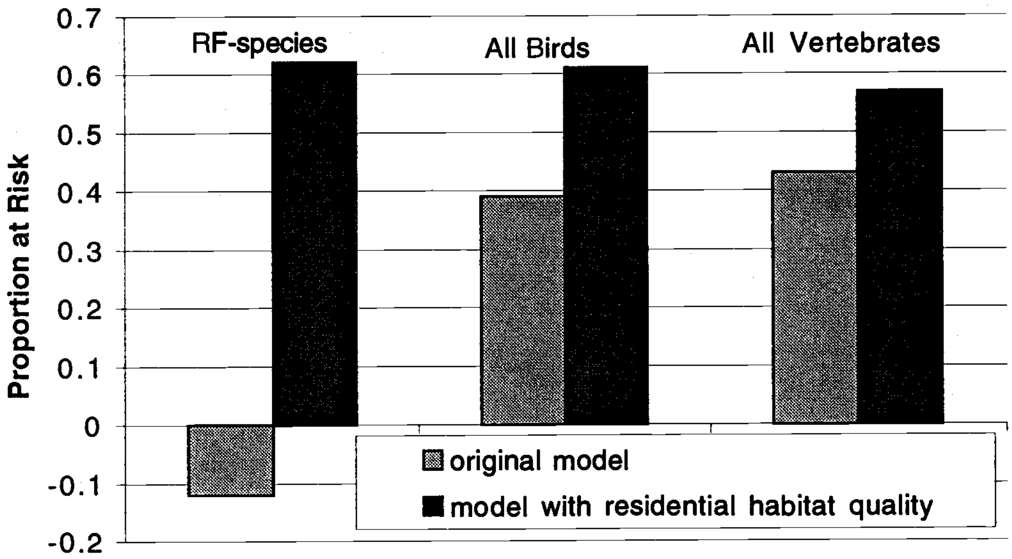

Figure 4: Risk to Habitat Abundance: Buildout Landscape

three are aerial feeders. There are no foliage or trunk gleaners in this group. No ground nesters were positively affected by the landscape change. Four species have protected nest types, and the two have arboreal, open nest types. Four species are year-round residents and two are neotropical migrants. No area sensitive species are found in this group. See Figure 6 for a summary.

Figure 6: Species Risk Groups and Life History Traits for Buildout Landscape

Life History Trait	Negatively Impacted Group (44 species)		Minimally Impacted Group (12 species)		Positively Impacted Group (6 species)	
	# of species	% of group	# of species	% of group	# of species	% of group
Diet Type						
carnivore	5	11	1	8	0	0
insectivore	26	59	6	50	4	67
omnivore	13	30	5	42	2	33
Foraging Strategy						
foliage/trunk gleaner	22	50	2	17	0	0
ground feeder	10	23	5	42	3	50
aerial feeder	10	23	5	42	3	50
other	2	4	0	0	0	0
Nest Type and Placement						
arboreal, open nest	19	43	4	33	2	33
protected nest	14	32	6	50	4	67
shrub nest	5	11	2	17	0	0
ground nest	6	14	0	0	0	0
Migratory Status						
resident species	18	41	6	50	4	67
short distance migrant	7	16	2	17	0	0
neotropical migrant	19	43	4	33	2	33
Other						
area sensitive species	10	23	3	25	0	0

4.3.2 SPINE LANDSCAPE

Only two risk groups were predicted for the Spine landscape. No species had losses of habitat abundance severe enough to place them in the negatively impacted group. All species were minimally impacted except for six species which were positively impacted by the landscape change. These six species are the same six species that were positively affected in the Buildout landscape (see discussion above).

Since species in the Spine landscape fall into only two risk classes and the overwhelming majority of species (90%) fall into one risk class (see Figure 7), life history traits will not be discussed in connection with the risk classes of this landscape. The following discussion of life history traits and risk groups will focus on the Buildout landscape.

Figure 7: Species Risk Groups and Life History Traits for Spine Landscape

Life History Trait	Minimally Impacted Group (56 species)		Positively Impacted Group (6 species)	
	# of species	% of group	# of species	% of group
Diet Type				
carnivore	6	11	0	0
insectivore	32	57	4	67
omnivore	18	32	2	33
Foraging Strategy				
foliage/trunk gleaner	24	43	0	0
ground feeder	15	27	3	50
aerial feeder	15	27	3	50
other	2	3	0	0
Nest Type and Placement				
arboreal, open nest	23	41	2	33
protected nest	20	36	4	67
shrub nest	7	12	0	0
ground nest	6	11	0	0
Migratory Status				
resident species	24	43	4	67
short distance migrant	9	16	0	0
neotropical migrant	23	41	2	33
Other				
area sensitive species	13	23	0	0

5.0 Discussion

5.1 EFFECT OF HABITAT QUALITY ON RISK PREDICTIONS

The increase in predicted risk to RF-species with the modification of the model was dramatic. From a 0.12 *gain* in habitat abundance for RF-species, the risk climbed to 0.62 *loss* of habitat abundance in the Buildout landscape. This yielded a much different assessment of the risk of landscape change for birds associated with residential and forest habitats. The predicted risk to RF-species increased by 0.74 when the model included habitat quality. In other words, the original prediction overestimated the mean habitat available to RF-species by 74%. The original predictions indicated there was no risk to RF-species, since residential habitat increased by 200%. The risk to RF-species, with inclusion of residential habitat quality in the model, was in fact at a high level for the Buildout landscape. This high level of risk was due to removal of 80% of the forest habitats from the landscape (see Figure 2). Once the value of the increasing residential area was scaled into proportion by using a density-weighted measure of habitat quality, birds associated with both residential and forest habitat were predicted to be severely affected.

Underestimation of risk for the group of RF-species affected the predictions of risk for all bird species and all vertebrate species in the county. The original prediction of risk in the Buildout landscape for all bird species was 0.22 lower than the modified prediction, and the original prediction of risk for all vertebrate species was 0.14 lower than the modified prediction. In other words, the original prediction overestimated the habitat available to all bird species by 22%, and the original prediction overestimated the habitat available to all vertebrates by 14%. The effect of considering habitat quality for a subset of species on the predictions of risk for larger groups of species indicated the importance of including habitat quality in such assessments.

The influence of residential habitat quality on the prediction of risk to RF-species in the Spine landscape was similar to that of the Buildout landscape. The degree of influence was, however, smaller in magnitude. Because the Spine landscape retained half of its forest habitats, the loss of habitat for these species was smaller than that encountered in the Buildout landscape. The increase in residential habitat was only 94% versus the 200% gain in the Buildout landscape; thus the overestimation of total habitat abundance was not as severe in the original analysis of the Spine landscape. The original prediction of risk to RF-species was 0.31 lower than the prediction with habitat quality included. The effect of underestimating the risk for the subset of RF-species on the larger groups of species was similar to that of the Buildout landscape. The risk to all bird species was 0.13 lower in the original model, and the risk to all vertebrate species was 0.08 lower in the original model.

The risk to all bird and all vertebrate species was much higher in the Buildout landscape than in the Spine landscape. The lesser amount of risk in the planned landscape, Spine, was due to the preservation of portions of a wide variety of habitat types. Forest, agriculture and shrubland habitats were all present in significant amounts in the Spine landscape (see Figure 2). These habitats were greatly reduced in the Buildout landscape, which was dominated by residential habitat.

The addition of density-derived habitat quality to the model improved the realism of the model. Basing habitat quality on field measures of wildlife population densities increased the model's representation of the ecological needs of species. The modification of the model scaled the quality of different habitat types to reflect the value of such habitats in nature.

The effort and time involved in obtaining measures of habitat quality are definitely worthwhile since the predicted risks of the modified model more accurately reflect the true risk to species due to landscape change. Information on the relative quality of different habitats could improve the predictions of biodiversity risk models by incorporating ecological and life history traits of the species involved.

The model used in this research could be applied to any local landscape where change is likely to occur. With data on the habitat types in the landscape, the species present, species-habitat associations, future landscape options and habitat cover, and the population densities of the species in the region, predictions of risk to biodiversity due to landscape change could be made for any local landscape.

Further research is needed in assessing habitat quality of all habitat types, especially for those species associated with residential, shrubland, agriculture, and wetland habitats. With further life history and demographic data, such models could begin to predict the effects of landscape change on the population viability of wildlife species. The information needed includes population densities, reproductive success, death rate, birth rate, emigration and immigration rates for species in all habitat types. Prediction of the effect of landscape change on the population viability of wildlife species would be of utmost utility in assessing the true ability of a landscape to contribute to long-term biodiversity on a local scale.

5.2 RF-SPECIES: RISK GROUPS AND LIFE HISTORY TRAITS

The results of the analysis of species risk groups and life history traits were qualitative. The purpose of this analysis was to explore possible correlations between risk status and life history traits of RF-species. Foliage and tree trunk gleaners were seriously affected by the landscape change in the Buildout landscape. Of 24 foliage or tree trunk gleaners in the county, 22 were negatively affected (92% negatively affected), while 16 out of 36 species (44%) that feed on the ground or in the air benefited from the landscape change. Buildout landscape was dominated by residential areas, which are structurally simple. Residential areas are characterized by large amounts of open lawns and only a few, scattered, large trees. These characteristics favor ground and aerial feeders. Foliage and tree trunk gleaners rely on structurally diverse environments such as forests, which provide diverse plant surfaces on which to feed. In the Buildout landscape, forest areas decrease significantly, decreasing the feeding habitat available to foliage and tree trunk gleaners.

All species that were minimally or positively affected by the landscape change had arboreal nests, shrub nests, or protected nests. All ground nesting species were negatively affected by the change. The disturbances present in residential areas make successful breeding by ground nesters very difficult; while those species that nest out of harm's way in trees and inside protected cavities do better.

The majority of neotropical migrants that breed in the county (76%) were negatively affected by the landscape change. This indicates that a landscape that is dominated by residential areas does not provide habitat acceptable to neotropical migrants, which have short breeding seasons and are sensitive to breeding disturbances found in residential areas. Most area sensitive species (77%) were also negatively affected, indicating that these species inhabit residential areas rarely, probably due to their preference for large areas of unbroken forest habitat. The characteristic of area sensitivity was positively correlated with lower population densities in residential habitat in this study. Other research indicates that the addition of patch size to this model would result in an increase in the predicted risk to area sensitive species

(Santelmann, M., D. White, K. Freemark, J. Sifneos. 1996. Modeling risks of extinction for forest birds based on spatial use of habitat. Unpublished data).

6.0 SUMMARY

There were significant differences between the population densities of bird species in residential habitats and in forest habitats. Incorporating a measure of relative habitat quality based on this difference in population densities into a model of the effect of landscape change on vertebrate diversity resulted in a significant increase in the predicted risk to species' habitat abundance. The consideration of habitat quality is important to the accuracy and realism of such models and is thus well worth the time and effort.

Examination of the life history traits of species revealed some possible causes for their risk status due to landscape change that involved an increase in residential areas at the cost of natural habitats. Those species predicted to be at high risk included ground nesters, foliage and tree trunk gleaners, neotropical migrants, and area sensitive species. Such characteristics make these species less likely to thrive in residential areas. The few species predicted to thrive under the landscape change were ground and aerial feeders that had arboreal and protected nest types. These behaviors enable species to capitalize on the conditions present in residential areas.

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APPENDICES

Appendix A: Residential and Forest Densities for 62 Bird Species associated with both Residential and Forest Habitats in Monroe County, PA. NA in residential sources indicates no residential densities were available for that species. Density = birds per 40 hectares. See Appendix B for scientific names.

Species Common Name	Residential Density	Forest Density	Residential Sources	Forest Sources
Green-backed Heron	0.06	2.50	DeGraaf and Wentworth 1986; Graber et al. 1978	Graber and Graber 1963
Sharp-shinned Hawk	0.00	0.02	NA	Craighead and Craighead 1969
Cooper's Hawk	0.00	0.20	NA	DeGraaf and Rudis 1986
Red-tailed Hawk	0.00	0.05	NA	DeGraaf and Rudis 1986
Mourning Dove	8.15	11.59	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982	DeGraaf and Rudis 1986
Black-billed Cuckoo	0.00	8.60	NA	DesGranges 1980
Yellow-billed Cuckoo	0.07	5.33	DeGraaf and Wentworth 1986	DeGraaf and Rudis 1986
Eastern Screech-Owl	0.06	0.06	NA	DeGraaf and Rudis 1986
Great Horned Owl	0.00	0.04	NA	DeGraaf and Rudis 1986
Common Nighthawk	4.00	4.00	NA	DeGraaf and Rudis 1986
Whip-poor-will	0.00	2.21	NA	DeGraaf and Rudis 1986; DesGranges 1980
Ruby-throated Hummingbird	0.17	8.00	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982; Van Velzen and Van Velzen 1983	DeGraaf and Rudis 1986
Red-headed Woodpecker	1.00	10.50	Graber et al. 1977	DeGraaf and Rudis 1986
Red-bellied Woodpecker	1.97	18.96	Hooper et al. 1975; Graber et al. 1977	DeGraaf and Rudis 1986
Downy Woodpecker	0.65	19.14	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982; Graber et al. 1977	DeGraaf and Rudis 1986

Appendix A (continued)

Species Common Name	Residential Density	Forest Density	Residential Sources	Forest Sources
Hairy Woodpecker	0.60	6.69	DeGraaf and Wentworth 1981, 1986; Graber et al. 1977	DeGraaf and Rudis 1986
Northern Flicker	4.44	18.96	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982; Graber et al. 1977	DeGraaf and Rudis 1986
Pileated Woodpecker	0.36	2.00	DeGraaf and Wentworth 1986	DeGraaf and Rudis 1986
Eastern Wood-Pewee	1.17	6.00	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982	DeGraaf and Rudis 1986
Eastern Phoebe	1.06	1.16	DeGraaf and Wentworth 1981, 1986	DeGraaf and Rudis 1986
Great Crested Flycatcher	2.10	7.48	DeGraaf and Wentworth 1981, 1986; Graber et al. 1974	DeGraaf and Rudis 1986
Eastern Kingbird	0.29	5.50	DeGraaf and Wentworth 1981, 1986	DeGraaf and Rudis 1986
Tree Swallow	0.79	12.74	DeGraaf and Wentworth 1981, 1986; Erskine 1972, 1976; Van Velzen 1979; Van Velzen and Van Velzen 1982	Erskine 1971; Erskine 1980
Bank Swallow	0.00	43.01	NA	Graber and Graber 1963
Cliff Swallow	18.35	18.35	NA	Erskine 1972
Barn Swallow	4.96	3.20	DeGraaf and Rudis 1986	DeGraaf and Rudis 1986
Blue Jay	17.02	5.00	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982; Thomas et al. 1977; Williamson and DeGraaf 1980	DeGraaf and Rudis 1986; DesGranges 1980
American Crow	0.68	0.80	DeGraaf and Wentworth 1981, 1986	DeGraaf and Rudis 1986
Black-capped Chickadee	6.10	27.03	DeGraaf and Wentworth 1981, 1986; Thomas et al. 1977	DesGranges 1980
Tufted Titmouse	1.49	13.03	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982	DeGraaf and Rudis 1986; DesGranges 1980
Red-breasted Nuthatch	0.16	12.90	DeGraaf and Wentworth 1981, 1986	DesGranges 1980

Appendix A (continued)

Species Common Name	Residential Density	Forest Density	Residential Sources	Forest Sources
White-breasted Nuthatch	2.34	6.72	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982	DesGranges 1980
Brown Creeper	0.07	8.60	DeGraaf and Wentworth 1981, 1986	DesGranges 1980
Carolina Wren	30.77	7.75	Geibert 1980; Beissinger and Osborne 1982	DeGraaf and Rudis 1986
House Wren	6.66	50.00	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982; Thomas et al. 1977	DeGraaf and Rudis 1986
Blue-gray Gnatcatcher	0.07	7.01	DeGraaf and Wentworth 1986; Graber et al. 1979	DeGraaf and Rudis 1986
Eastern Bluebird	25.00	18.87	DeGraaf and Rudis 1986	DeGraaf and Rudis 1986
Veery	0.00	15.69	NA	DeGraaf and Rudis 1986
Wood Thrush	2.63	10.99	DeGraaf and Wentworth 1981, 1986; Williamson and DeGraaf 1980	DeGraaf and Rudis 1986
American Robin	70.18	13.99	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982; Thomas et al. 1977; Williamson and DeGraaf 1980	DeGraaf and Rudis 1986
Gray Catbird	6.88	21.62	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982; Thomas et al. 1977; Williamson and DeGraaf 1980	DeGraaf and Rudis 1986
Brown Thrasher	0.11	75.47	DeGraaf and Wentworth 1981, 1986; Thomas et al. 1977	DeGraaf and Rudis 1986; DesGranges 1980
Cedar Waxwing	0.12	31.25	DeGraaf and Wentworth 1981, 1986	DeGraaf and Rudis 1986
White-eyed Vireo	0.00	35.40	NA	DeGraaf and Rudis 1986
Solitary Vireo	0.12	17.02	DeGraaf and Wentworth 1986	DeGraaf and Rudis 1986; DesGranges 1980
Yellow-throated Vireo	0.00	7.50	NA	DeGraaf and Rudis 1986

Appendix A (continued)

Species Common Name	Residential Density	Forest Density	Residential Sources	Forest Sources
Warbling Vireo	0.08	10.00	DeGraaf and Wentworth 1986	DeGraaf and Rudis 1986
Red-eyed vireo	1.60	51.95	DeGraaf and Wentworth 1981, 1986	DeGraaf and Rudis 1986
Yellow Warbler	0.49	9.26	DeGraaf and Wentworth 1981, 1986	DeGraaf and Rudis 1986
Ovenbird	0.14	25.00	DeGraaf and Wentworth 1981, 1986	DeGraaf and Rudis 1986
Common Yellowthroat	0.24	50.00	DeGraaf and Wentworth 1981, 1986	DeGraaf and Rudis 1986; DesGranges 1980
Scarlet Tanager	0.67	14.98	DeGraaf and Wentworth 1981, 1986	DeGraaf and Rudis 1986
Northern Cardinal	10.05	22.99	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982; Williamson and DeGraaf 1980	DeGraaf and Rudis 1986
Rose-breasted Grosbeak	0.18	17.39	DeGraaf and Wentworth 1981, 1986	DesGranges 1980
Indigo Bunting	0.12	68.97	DeGraaf and Wentworth 1986	DeGraaf and Rudis 1986
Rufous-sided Towhee	0.38	32.00	DeGraaf and Wentworth 1981, 1986	DeGraaf and Rudis 1986
Chipping Sparrow	4.84	18.02	DeGraaf and Wentworth 1981, 1986; Thomas et al. 1977	DeGraaf and Rudis 1986
Field Sparrow	0.03	47.06	DeGraaf and Wentworth 1986; Beissinger and Osborne 1982	DeGraaf and Rudis 1986
Common Grackle	15.21	15.27	DeGraaf and Wentworth 1981, 1986; Beissinger and Osborne 1982	Erskine 1980
Brown-headed Cowbird	0.23	23.53	DeGraaf and Wentworth 1986	DeGraaf and Rudis 1986
Orchard Oriole	14.98	10.00	DeGraaf and Rudis 1986	DeGraaf and Rudis 1986
Northern Oriole	3.96	10.00	DeGraaf and Wentworth 1981, 1986; Thomas et al. 1977	DeGraaf and Rudis 1986

Appendix B: Bird Species Associated with both Residential and Forest Habitats in Monroe County, PA, and Their Habitat Associations

Habitat Categories:

1	commercial-industrial-transportation	8	hemlock forest
2	residential	9	white pine forest
3	agricultural	10	white pine-hardwoods forest
4	lacustrine limnetic	11	oak-heath forest
5	lacustrine littoral	12	sugar maple-red oak forest
6	palustrine	13	sugar maple-ash-basswood forest
7	shrublands		

A value of 0 for a species in a habitat category indicates low probability of occurrence, and 1 indicates high probability of occurrence (Smith and Richmond 1994, White et al. submitted). The residential habitat values (column 2) are ratios that represent relative quality of residential habitat when compared to forest habitat. Note: * indicates ratio was estimated from published habitat association descriptions, not based on published population densities.

Scientific Name	Common Name	1	2	3	4	5	6	7	8	9	10	11	12	13
Butorides striatus	Green-backed Heron	0	0.024	1	1	1	1	0	0	0	1	1	1	1
Accipiter striatus	Sharp-shinned Hawk*	0	0.000	1	0	0	0	1	1	1	1	1	1	1
Accipiter cooperii	Cooper's Hawk*	0	0.000	1	0	0	0	1	1	1	1	1	1	1
Buteo jamaicensis	Red-tailed Hawk*	0	0.000	1	0	0	0	1	1	1	1	1	1	1
Zenaida macroura	Mourning Dove	0	0.703	1	0	0	0	0	0	1	1	1	1	1
Coccyzus erythropthalmus	Black-billed Cuckoo*	0	0.000	1	0	0	0	1	0	1	1	1	1	1
Coccyzus americanus	Yellow-billed Cuckoo	0	0.013	1	0	0	0	1	0	0	1	1	1	1
Otus asio	Eastern Screech-Owl*	0	1.000	1	0	0	0	1	1	1	1	1	1	1
Bubo virginianus	Great Horned Owl*	0	0.000	1	0	0	0	1	1	1	1	1	1	1
Chordeiles minor	Common Nighthawk*	1	1.000	1	0	0	0	1	1	1	1	1	1	1
Caprimulgus vociferus	Whip-poor-will*	0	0.000	1	0	0	0	1	0	1	1	1	1	1
Archilochus colubris	Ruby-throated Hummingbird	0	0.021	1	0	0	0	1	1	1	1	1	1	1
Melanerpes erythrocephalus	Red-headed Woodpecker	0	0.095	1	0	0	0	0	0	0	1	1	1	1
Melanerpes carolinus	Red-bellied Woodpecker	0	0.104	1	0	0	0	0	0	1	1	1	1	1
Picoides pubescens	Downy Woodpecker	0	0.034	1	0	0	0	1	1	1	1	1	1	1
Picoides villosus	Hairy Woodpecker	0	0.090	1	0	0	0	1	1	1	1	1	1	1

Appendix B (continued)

Scientific Name	Common Name	1	2	3	4	5	6	7	8	9	10	11	12	13
Colaptes auratus	Northern Flicker	0	0.234	1	0	0	0	1	1	1	1	1	1	1
Dryocopus pileatus	Pileated Woodpecker	0	0.180	1	0	0	0	0	1	1	1	1	1	1
Contopus virens	Eastern Wood-Pewee	0	0.195	1	0	0	0	0	1	1	1	1	1	1
Sayornis phoebe	Eastern Phoebe	0	0.914	1	0	0	0	0	1	1	1	1	1	1
Myiarchus crinitus	Great Crested Flycatcher	0	0.281	0	0	0	0	0	1	1	1	1	1	1
Tyrannus tyrannus	Eastern Kingbird	0	0.053	1	0	0	0	0	0	0	1	1	1	1
Tachycineta bicolor	Tree Swallow	0	0.062	1	1	1	1	1	0	0	1	1	1	1
Riparia riparia	Bank Swallow*	0	0.000	1	0	0	0	1	0	0	1	1	1	1
Hirundo pyrrhonota	Cliff Swallow*	0	1.000	1	0	0	0	0	0	0	1	1	1	1
Hirundo rustica	Barn Swallow	1	1.550	1	0	0	0	1	0	0	1	1	1	1
Cyanocitta cristata	Blue Jay	0	3.404	1	0	0	0	1	1	1	1	1	1	1
Corvus brachyrhynchos	American Crow	1	0.850	1	0	0	0	1	1	1	1	1	1	1
Parus atricapillus	Black-capped Chickadee	0	0.226	1	0	0	0	1	1	1	1	1	1	1
Parus bicolor	Tufted Titmouse	0	0.114	1	0	0	0	1	0	1	1	1	1	1
Sitta canadensis	Red-breasted Nuthatch	0	0.012	0	0	0	0	0	1	1	1	0	0	0
Sitta carolinensis	White-breasted Nuthatch	0	0.348	1	0	0	0	0	0	1	1	1	1	1
Certhia americana	Brown Creeper	0	0.008	1	0	0	0	0	1	1	1	1	1	1
Thryothorus ludovicianus	Carolina Wren	0	3.970	1	0	0	0	1	0	0	1	1	1	1
Troglodytes aedon	House Wren	0	0.133	1	0	0	0	1	0	0	1	1	1	1
Polioptila caerulea	Blue-gray Gnatcatcher	0	0.010	1	0	0	0	0	0	0	1	1	1	1
Sialia sialis	Eastern Bluebird	0	1.325	1	0	0	0	0	0	0	0	1	0	0
Catharus fuscescens	Veery*	0	0.000	0	0	0	0	0	1	1	1	1	1	1
Hylocichla mustelina	Wood Thrush	0	0.239	0	0	0	0	0	1	1	1	1	1	1
Turdus migratorius	American Robin	0	5.016	1	0	0	0	1	1	1	1	1	1	1
Dumetella carolinensis	Gray Catbird	0	0.318	1	0	0	0	1	0	0	1	1	1	1
Toxostoma rufum	Brown Thrasher	0	0.001	1	0	0	0	1	0	0	1	1	1	1
Bombycilla cedrorum	Cedar Waxwing	0	0.004	1	0	0	0	1	0	0	1	1	1	1
Vireo griseus	White-eyed Vireo*	0	0.000	0	0	0	0	0	0	0	1	1	1	1
Vireo solitarius	Solitary Vireo	0	0.007	0	0	0	0	0	1	1	1	0	0	0
Vireo flavifrons	Yellow-throated Vireo*	0	0.000	0	0	0	0	0	0	0	0	1	1	1
Vireo gilvus	Warbling Vireo	0	0.008	1	0	0	0	0	0	0	0	0	1	1

Appendix B (continued)

Scientific Name	**Common Name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Vireo olivaceus	Red-eyed Vireo	0	0.031	1	0	0	0	0	0	1	1	1	1	1
Dendroica petechia	Yellow Warbler	0	0.053	1	0	0	0	1	0	0	0	1	1	1
Seiurus aurocapillus	Ovenbird	0	0.006	0	0	0	0	0	1	1	1	1	1	1
Geothlypis trichas	Common Yellowthroat	0	0.005	1	0	0	0	1	0	0	1	1	1	1
Piranga olivacea	Scarlet Tanager	0	0.045	0	0	0	0	0	1	1	1	1	1	1
Cardinalis cardinalis	Northern Cardinal	0	0.437	1	0	0	0	0	0	0	0	1	1	1
Pheucticus ludovicianus	Rose-breasted Grosbeak	0	0.010	0	0	0	0	0	0	0	1	1	1	1
Passerina cyanea	Indigo Bunting	0	0.002	1	0	0	0	1	0	0	0	1	1	1
Pipilo erythrophthalmus	Rufous-sided Towhee	0	0.012	1	0	0	0	1	0	0	1	1	1	1
Spizella passerina	Chipping Sparrow	0	0.269	1	0	0	0	1	0	1	1	1	1	1
Spizella pusilla	Field Sparrow	0	0.001	1	0	0	0	1	0	0	0	1	0	0
Quiscalus quiscula	Common Grackle	0	0.996	1	0	0	0	1	1	1	1	1	1	1
Molothrus ater	Brown-headed Cowbird	0	0.010	1	0	0	0	1	1	1	1	1	1	1
Icterus spurius	Orchard Oriole	0	1.498	1	0	0	0	0	0	0	0	1	1	1
Icterus galbula	Northern Oriole	0	0.396	1	0	0	0	0	0	0	0	1	1	1

Appendix C: Life History Traits and Risk Groups for Bird Species Associated with both Residential and Forest Habitats in Monroe County, PA. See Appendix B for scientific names.

__Key__:

Foraging Strategy: c = carnivore, i = insectivore, o = omnivore, g = ground feeder, f = foliage gleaner, t = trunk gleaner, a = aerial feeder (Degraaf and Rudis 1986, Ehrlich et al. 1988).

Nest Type and Placement: t = tree nester, s = shrub nester, c = cavity nester, l = ledge nester, g = ground nester, p = protected nest design other than cavities (Degraaf and Rudis 1986, Ehrlich et al. 1988.).

Migratory Status: r = resident, sd = short distance migrant, n= neotropical migrant (DeGraaf and Rudis 1986).

Area Sensitivity: y = area sensitive, n = not area sensitive (Robbins 1989)

Risk Group: 1 = Habitat Abundance Ratio 1.1 and above (positively impacted), 2 = 0.5-1.1 (minimally impacted), 3 = 0.0-0.5 (negatively impacted).

Species Common Name	Foraging Strategy	Nest Type & Placement	Migratory Status	Area Sensitivity	Buildout Risk Group	Spine Risk Group
Green-backed Heron	c	t	sd	n	3	2
Sharp-shinned Hawk	c:a	t	r	n	3	2
Cooper's Hawk	c:a	t	r	n	3	2
Red-tailed Hawk	c:a	t	r	n	3	2
Mourning Dove	o:g	t	r	n	2	2
Black-billed Cuckoo	i:f	t,s	n	n	3	2
Yellow-billed Cuckoo	i:f	t,s	n	n	3	2
Eastern Screech-Owl	c:a	c	r	n	2	2
Great Horned Owl	c:a	t	r	n	3	2
Common Nighthawk	i:a	l	n	n	2	2
Whip-poor-will	i:a	g	sd	n	3	2
Ruby-throated Hummingbird	o	t	n	n	3	2
Red-headed Woodpecker	o:a	c	r	n	3	2
Red-bellied Woodpecker	i:t	c	r	y	3	2

Appendix C (continued)

Downy Woodpecker	i:t	c	r	n	3	2
Hairy Woodpecker	i:t	c	r	y	3	2
Northern Flicker	i:g	c	r	n	3	2
Pileated Woodpecker	i:t	c	r	y	3	2
Eastern Wood-Pewee	i:a	t	n	n	3	2
Eastern Phoebe	i:a	l	sd	n	2	2
Great Crested Flycatcher	i:a	c	n	y	2	2
Eastern Kingbird	i:a	t	n	n	3	2
Tree Swallow	i:a	c	n	n	3	2
Bank Swallow	i:a	c	n	n	3	2
Cliff Swallow	i:a	l:p	n	n	2	2
Barn Swallow	i:a	l	n	n	1	1
Blue Jay	o:g	t	r	n	1	1
American Crow	o:g	t	r	y	2	2
Black-capped Chickadee	o:f	c	r	n	3	2
Tufted Titmouse	o:f	c	r	y	3	2
Red-breasted Nuthatch	i:t	c	r	n	3	2
White-breasted Nuthatch	i:t	c	r	y	2	2
Brown Creeper	i:t	t:p	r	n	3	2
Carolina Wren	i:g	c	r	n	1	1
House Wren	i:g	c	sd	n	3	2
Blue-gray Gnatcatcher	i:f	t	n	n	3	2
Eastern Bluebird	i:a	c	r	n	1	1
Veery	i:g	g,s	n	y	3	2
Wood Thrush	o:g	t	n	y	3	2
American Robin	o:g	t	r	n	1	1
Gray Catbird	o:g	s	sd	n	2	2
Brown Thrasher	o:g	s,g	sd	n	3	2

Appendix C (continued)

Cedar Waxwing	o:f	t	r	n	3	2
White-eyed Vireo	i:f	s	sd	n	3	2
Solitary Vireo	i:f	t	n	n	3	2
Yellow-throated Vireo	i:t	t	n	n	3	2
Warbling Vireo	i:f	t	n	n	3	2
Red-eyed Vireo	i:f	s	n	y	3	2
Yellow Warbler	i:f	s	n	n	3	2
Ovenbird	i:g	g	n	y	3	2
Common Yellowthroat	i:f	g,s	sd	n	3	2
Scarlet Tanager	i:f	t	n	y	3	2
Northern Cardinal	o:g	s	r	n	2	2
Rose-breasted Grosbeak	o:f	t	n	y	3	2
Indigo Bunting	o:f	s	n	n	3	2
Rufous-sided Towhee	o:g	g,s	r	n	3	2
Chipping Sparrow	o:g	s	sd	n	3	2
Field Sparrow	o:g	g,s	r	n	3	2
Common Grackle	o:g	t	r	n	2	2
Brown-headed Cowbird	o:g	t	r	n	3	2
Orchard Oriole	i:f	t:p	n	n	1	1
Northern Oriole	i:f	t:p	n	n	2	2