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HABITAT USE BY SPRUCE GROUSE IN A FRAGMENTED SYSTEM

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By

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This thesis by Laurel A. Hill is recommended for approval by the student's Thesis Committee and Department Head in the Department of Biology and by the Assistant Provost of Graduate Education and Research.

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ABSTRACT

HABITAT USE BY SPRUCE GROUSE IN A FRAGMENTED SYSTEM

By

Laurel A. Hill

The spruce grouse is a boreal obligate species that has been protected in Michigan since 1915 (Ammann 1963). Despite protection, the status of spruce grouse is uncertain in Michigan and other parts of the Midwest, and there have been few attempts at large-scale surveys or monitoring (Williamson et al. 2008). I studied a population of spruce grouse near the southern edge of their range on the Yellow Dog Plains in Marquette County, Michigan.

I investigated fecal pellet counts as a possible method to assess spruce grouse presence and habitat use. My results validated the use of fecal pellet occurrence as an indicator to habitat use. I used these data to determine which habitat patches were used by spruce grouse.

Structure and composition of habitat used by spruce grouse were described on the Yellow Dog Plains at the levels of forest patch, and point of presence. I used vegetation cover and composition metrics, as well as measures of patch connectivity, size and complexity to predict presence of spruce grouse. Patch level habitat use by spruce grouse on the Yellow Dog Plains was greatly influenced by patch area and canopy density ($Canonical\ Correlation^2$=0.36, df=2, P<0.001)

I analyzed historical aerial photography of the Yellow Dog Plains in Marquette County, Michigan, from 1937 to 2011 to determine how land cover change influenced spruce grouse habitat. To predict the likely effect of these changes, I created an index to habitat quality (a combination of patch size, and canopy coverage). Based upon these results, the Yellow Dog Plains has become increasingly fragmented and high quality spruce grouse habitat has decreased and is being replaced by intermediate quality habitat.

DEDICATION

To the spruce grouse who tolerated my presence for countless hours,
And to the scientists, naturalists, and passersby who may also be inspired by them.

To an advisor and good friend, Dr. Alan Rebertus,
For encouraging my sense of adventure and curiosity.

Finally, to the late Dr. William Robinson,
Whose research sparked a passion that lives on in many.

ACKNOWLEDGEMENTS

The inspiration for this project is owed to Dr. William Robinson. His book "Fool Hen" and intimate knowledge of the Yellow Dog Plains, combined with the legacy he left at Northern Michigan University, helped build the backbone of this study. My advisor, Dr. Patrick Brown, provided indefatigable support and encouragement. As an undergraduate, I was inspired by Dr. Brown's background and experience and I am honored to have worked with him. I am grateful to have the help of two very smart people on my committee, Dr. John Bruggink and Dr. Alan Rebertus. This project is a tribute to the great enthusiasm and encouragement I received from my excellent committee. Christie Deloria provided encouragement and valuable insight as I progressed through my graduate career, and made it possible for me to leave work, as needed, to write this thesis. A special thanks to a great friend ('the true blue'), Leon Russell Katona who provided unlimited support, laughter, help, encouragement, and distractions when I needed them. I am grateful for all of the landowners and lessees who have allowed me to work on their property. Most notably the Michigan Department of Natural Resources, the members of the Huron Mountain Club, Plum Creek Timber Company, JML Heirs, LCC, the Yellow Dog Watershed Preserve, and Lundin Mining Corporation. Financial support came from the Huron Mountain Club Wildlife Federation, Northern Michigan University's Excellence in Education Award, Northern Michigan University's Department of Biology, and the Laughing Whitefish Audubon Society Research Award. Thank you to all who helped!

PREFACE

The inspiration for this project came from the text by Robinson (1980) "Fool Hen". This book features seminal research on spruce grouse (*Falcipennis canadensis*) conducted by Robinson and his graduate students in the 1960s and 1970s. The research specifically focuses on a small population of spruce grouse located the Yellow Dog Plains, a glacial outwash plain in northern Marquette County, Michigan. The purpose of Robinson et al.'s research was to understand the ecology of spruce grouse, and specifically investigate how they persist in small populations.

The Yellow Dog Plains is largely composed of timber harvest property and state lands. These lands have seemingly changed 50 years after the start of Robinson's research and I wondered how these changes may have affected the small population of spruce grouse there. Do spruce grouse still occur in areas that Robinson investigated 50 years ago? Is habitat use by spruce grouse influenced by landscape fragmentation? I was inspired by Robinson's seminal research and wanted to investigate the effects of landscape alteration on spruce grouse on the Yellow Dog Plains.

Each chapter is presented in a standalone manuscript in the style of the *Journal of Wildlife Management*.

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CHAPTER 1

THE USE OF FECAL DETECTION AS AN INDICATOR OF SPRUCE GROUSE PRESENCE

ABSTRACT

The objective of this study was to determine if fecal pellet occurrence was a reliable index to spruce grouse (*Falcipennis canadensis*) habitat use and to compare it with counts of spruce grouse flushed along transects. Many techniques have been used to survey grouse and estimate population sizes. Flushing and pointing dogs, drumming surveys, and call-back techniques are all popular methods for surveying grouse populations (Dorney et al. 1958, Robinson 1969, Schroeder and Boag 1989, Gutzwiller 1990). Many grouse researchers use radio telemetry, and some are starting to employ GPS satellite telemetry (Wegge et al. 2007, Anich et al. 2013a) to census populations and study habitat use. Fecal pellet counts may be a less costly method when research objectives are to determine spruce grouse presence or general habitat use in an area.

I searched for spruce grouse and fecal pellets along transects from May to September in 2013 and 2014. Feces were detected far more often than flushing occurrences, but every place where grouse were flushed, feces were present. My results suggest fecal pellet counts to be a reliable indicator of general habitat use by spruce grouse.

INTRODUCTION

The spruce grouse is widely distributed across a vast range, but lives in scattered, often isolated, low density populations tied to specific habitat features (Boag and Schroeder 1992). Movement between separate breeding and wintering ranges occurs at the individual level; 75% remain sedentary throughout life. Most of the spruce grouse that exhibit seasonal movements return to the same breeding sites each year (Boag and Schroeder 1992). This behavior, coupled with increased habitat fragmentation by roads and silviculture practices, may increase the vulnerability of spruce grouse to local extinction.

In Michigan, spruce grouse occupy islands of conifer stands resulting from fragmentation by human activity (Robinson 1980). Important forest types used by Midwestern spruce grouse include the ecotones around bogs with low-lying black spruce (*Picea mariana*) and tamarack (*Larix laricina*), cedar forests (*Thuja occidentalis*), upland jack pine (*Pinus banksiana*) and areas rich with ericaceous shrubs (Schroeder and Boag 1991, Anich et al. 2013a).

Many techniques have been used to study grouse and estimate population sizes. Flushing and pointing dogs are often used to survey grouse populations (Robinson 1969, Gutzwiller 1990). Drumming surveys are a popular method for studying ruffed grouse (*Bonasa umbellus*), and call-back methods have been effective with some grouse species (Dorney et al. 1958, Schroeder and Boag 1989). Many grouse researchers use radio telemetry, and some are starting to employ GPS satellite telemetry (Wegge et al. 2007, Anich et al. 2013a). Although these methods provide excellent quality data, they are relatively time consuming and costly. There is need for an inexpensive and efficient means of assessing populations and use of habitat.

I investigated the detection of spruce grouse feces as an indicator of habitat use. This research was designed to test the validity of field methods used in a larger study to understand the effects of habitat fragmentation on spruce grouse. Evans et al. (2007) investigated red grouse (*Lagopus lagopus scoticus*) feces as a predictor of population density and compared results with counts using dogs, and play back counts of territorial males. Although grouse density could be predicted with fecal counts, Evans et al. (2007) found that playback counts predicted grouse populations more accurately.

Flush counts and fecal pellet counts are both positive evidence of spruce grouse presence. The objective of this study was to determine if fecal pellet occurrence is a reliable index to spruce grouse presence and to compare it with counts of birds flushed from transects.

STUDY AREA

The Yellow Dog Plains (YDP) study area is located in northern Marquette County, Michigan. State forest covered about 1538 ha in scattered parcels. The total study area was about 1770 ha, of which about 70% was conifer forest, 5% woody wetlands, and 25% scrub shrub (Fry et al. 2011). The study area was dominated by jack pine (*Pinus banksiana*) and additional cover types included northern hardwood, white pine (*Pinus strobus*), upland open/semi-open lands, and lowland open/semi-open lands (Michigan Department of Natural Resources 2012).

The Yellow Dog Plains is an area of frequent land cover change. Timber stands are harvested every 45-50 years and the harvest cycle drives the disappearance and reappearance of habitat patches over time. Also, a local nickel-copper mine began excavation in 2014, and has facilitated the construction of a highway through the YDP. The YDP landscape featured a mosaic of several different patch types, and the change from one patch to the next was abrupt. An aerial view shows a patchwork pattern imprinted on the landscape by timber harvest (Figure 1.1).

METHODS

Fecal Pellet Detection as a Predictor of Grouse Occurrence

I searched for spruce grouse and their fecal pellets from May to September of 2013 and 2014 while walking at a slow pace along transects 150 m apart. I collected data along each transect in a random-systematic fashion. The first sample point on each transect was randomly selected using a random number generator (ranging from 0 to 150 m) and subsequent points were designated every 150 m, and at the observation of grouse or grouse feces. Sample points marked the center of 400 m^2 circular plots in which all vegetation data were collected. I also searched for fecal pellets during a 3-minute designated search interval in each 400 m^2 plot. Fecal pellets were identified by size and composition.

Spruce grouse detection locations and fecal pellet counts were used as indices of habitat use. If more than one grouse or pellet group was observed within a 400 m^2 circular area of each other, the observations were considered dependent and only the location of the first observation was sampled (i.e. two or more birds were considered as one observation). Grouse surveys were conducted simultaneously with vegetation sampling.

I used the point-centered quarter method to determine the importance value of tree species and basal area (Cottam and Curtis 1956, Mitchell 2007) at each point. Tree importance values were defined as a combination of relative density, relative size, and relative frequency of tree species (Mitchell 2007). I classified the 3 -dimensional vegetation community using the Relevè method to determine the abundance of species, life form groups (i.e. deciduous, coniferous, forb etc.), and height classes (i.e. 0.5 to 2 m, 2 to 5 m, 5 to 10 m, etc.) (Minnesota Department of Natural Resources 2007).

Two methods were used to measure horizontal and vertical vegetative cover and density at each point. I used a hand-held densitometer (convex model A, Forestry Suppliers spherical crown densitometer) to record horizontal canopy density in each cardinal direction at the center of every study point. I also used a 2 m Nudds vegetation profile board (Nudds 1997) to estimate vertical vegetative density and visual obstruction on the landscape at each point.

Vegetative data were used to summarize the composition and structure of contiguous habitat patches. I delineated habitat patches based on contiguity of continuous vegetation using satellite imagery (ESRI 2011) and ArcGIS 10.1. I used ArcMap software to measure landscape metrics including patch area (ha) and complexity (m/ha). A more detailed description of analysis of vegetation, and landscape fragmentation, can be found in Chapter 2 and Chapter 3, respectively (Hill 2015).

Statistical Analysis

I used Wilcoxon Matched Pairs to test the hypothesis that average detection rates of grouse occurrence indicators (grouse and fecal pellet observations) did not differ in 2013 and 2014. I surveyed 49 habitat patches for grouse indicators in 2013 and 2014. A subset of 25 patches were sampled in both years. Detection rate of grouse, or grouse feces did not statistically differ between 2013 and 2014 (Figure 1.2, df= 25, P>0.695 and *P*>0.981, respectively). This result justified grouping grouse indicators for both years in further analyses.

I classified patches by presence of grouse or grouse feces to visualize the agreement between grouse indicators. Patches were classified as (1) fecal pellets were detected and grouse were undetected, (2) fecal pellets were undetected and grouse were detected, (3) both fecal pellets and grouse were detected, and (4) both fecal pellets and grouse were not detected. The latter two classes are considered patches with “indicator agreement” because of supporting observations of fecal pellets and grouse. The first two classes are considered patches with “indicator disagreement” because of contradicting observations of fecal pellets and grouse. Grouse presence was determined by the presence of grouse fecal pellets or if grouse were observed.

I used McNemar’s test to address the null hypothesis that mean fecal pellet detection was the same in patches used and unused by spruce grouse (Haviland 1990). I used Cochran’s Q test to address the null hypothesis that mean frequency of patches with grouse indicators was equal in patches >13 ha and < 13 ha (the smallest reported home range on a similar cut-over landscape (Turcotte et al. 2000)). I also used Cochran's Q test to address the null hypothesis that mean frequency of indicator agreement was equal in patches >13 ha and <13 ha.

I aggregated data by patch size and used 3 size quantiles to obtain even and adequate sample sizes in each aggregate. Frequency of patch occupancy was determined for each size quantile. A chi-square test was used to test the hypothesis that frequency of patch occupancy differed across size. I also used a chi-square test to address the hypothesis that frequency of indicator agreement differed across patch size.

I further re-aggregated data into 3 complexity quantiles using area-to-edge ratio. A chi-square test was used to address the hypothesis that frequency of patch occupancy differed across patch complexity. I also used a chi-square test to address the hypothesis that frequency of occupancy agreement differed across patch complexity.

RESULTS

Grouse were detected in 28% of forest patches (*n*=14) and the number of detections ranged from 0 to 8 grouse per patch. The mean number of grouse detections in grouse-positive patches was 0.6 grouse per patch (*n*=14, $\bar{x}$ = 0.6/positive patch). In contrast, fecal pellets were detected in 75% of forest patches and detections ranged from 0 to 58 per forest patch (*n*=37, $\bar{x}$ = 7.0/positive patch).

Fecal pellets were present, but no flushes of spruce grouse were recorded, on 47% of surveyed patches (*n*=22, Figure 1.3). Patches with no detected fecal pellets or grouse composed 26% of sampled patches (*n*=13, Figure 1.3). There were no patches that had grouse occurrence without fecal pellet detection.

Fecal presence coincided with grouse presence 52% of the time and grouse presence matched fecal presence 100% of the time (Fig. 1.4, $P<0.001$). Feces were detected far more often than grouse, but feces were present at every location where grouse were flushed.

Presence of spruce grouse was not different in patches <13 ha (Figure 1.5, Q=1.33, df=1, *1-tailed P* =0.124) than in larger patches. Similarly, occupancy agreement was not different in patches >13 ha (Q=1.96, df=1, *1-tailed P*=0.081) than in smaller patches.

Frequency of grouse indicator presence in patches ranged from 0.47 to 0.94 in patch size quantiles (grouse detections/number of patches, Table 1.1). Frequency of presence differed across patch size (Fig. 1.6 *Phi and Cramer's V*=0.486, df=2, *1-tailed P*=0.001). In addition, the frequency of agreement between grouse indicators ranged from 0.59 to 0.69 and differed across patch size (Table 1.1, *Phi and Cramer's V*=0.315, df=2, *1-tailed P*=0.044,).

Frequency of patch occupancy ranged from 0.71 to 0.81 in patch complexity quantiles (grouse detections/number of patches, Table 1.2). Frequency of presence was not greater in complex patches (Fig 1.7, *Phi and Cramer's V*=0.102, df=2, *1-tailed P*= 0.388). Similarly, frequency of agreement between presence indicators was not greater in complex patches (Table 1.2, *Phi and Cramer's V*=0.084, df=2, *1-tailed P*= 0.421).

DISCUSSION

The inherent scarcity and secretive nature of spruce grouse presents a challenge in measuring the presence of spruce grouse and in statistically analyzing the data. Frequency of spruce grouse presence was highest in the largest habitat patches. This finding supports the hypothesis that spruce grouse require large contiguous patches of forest. Frequency of agreement between occupancy indicators was also greatest in the largest patches (Table 1.2). However, the agreement in frequency of presence in the middle patch size quantile was unexpectedly low.

This is may be due to small sample size but further research is needed to be sure. The significant trend in agreement frequency suggests that fecal pellet occurrence predicts grouse presence more accurately in large, contiguous habitat.

Spruce grouse are difficult to count because they are generally silent, are secretive and tend not to flush, and persist in relatively small populations (Robinson 1980, but see Szuba and Bendell 1983, Keppie 1987, Boag and Schroeder 1992). Fecal pellet counts may provide an efficient method to determine habitat use by spruce grouse.

If detection of fecal pellets is a good indicator of grouse presence, then I expected agreement of grouse presence and fecal presence to be more frequent than disagreement. I never flushed grouse where no fecal pellets were found. Further, I found moderate agreement between grouse presence and fecal pellet detections. These findings support fecal pellet detection as an indicator of habitat presence by spruce grouse.

MANAGEMENT IMPLICATIONS

To my knowledge, there are no large scale attempts to surveying for spruce grouse in the Midwest. Lack of survey efforts is due, in part, to limited capacity and financial support. Surveying for spruce grouse is an intensive process because of their silent and secretive nature. Using fecal pellets as an indicator of spruce grouse may provide a quicker and more realistic way to survey general presence and habitat use in management scenarios.

TABLES AND FIGURES

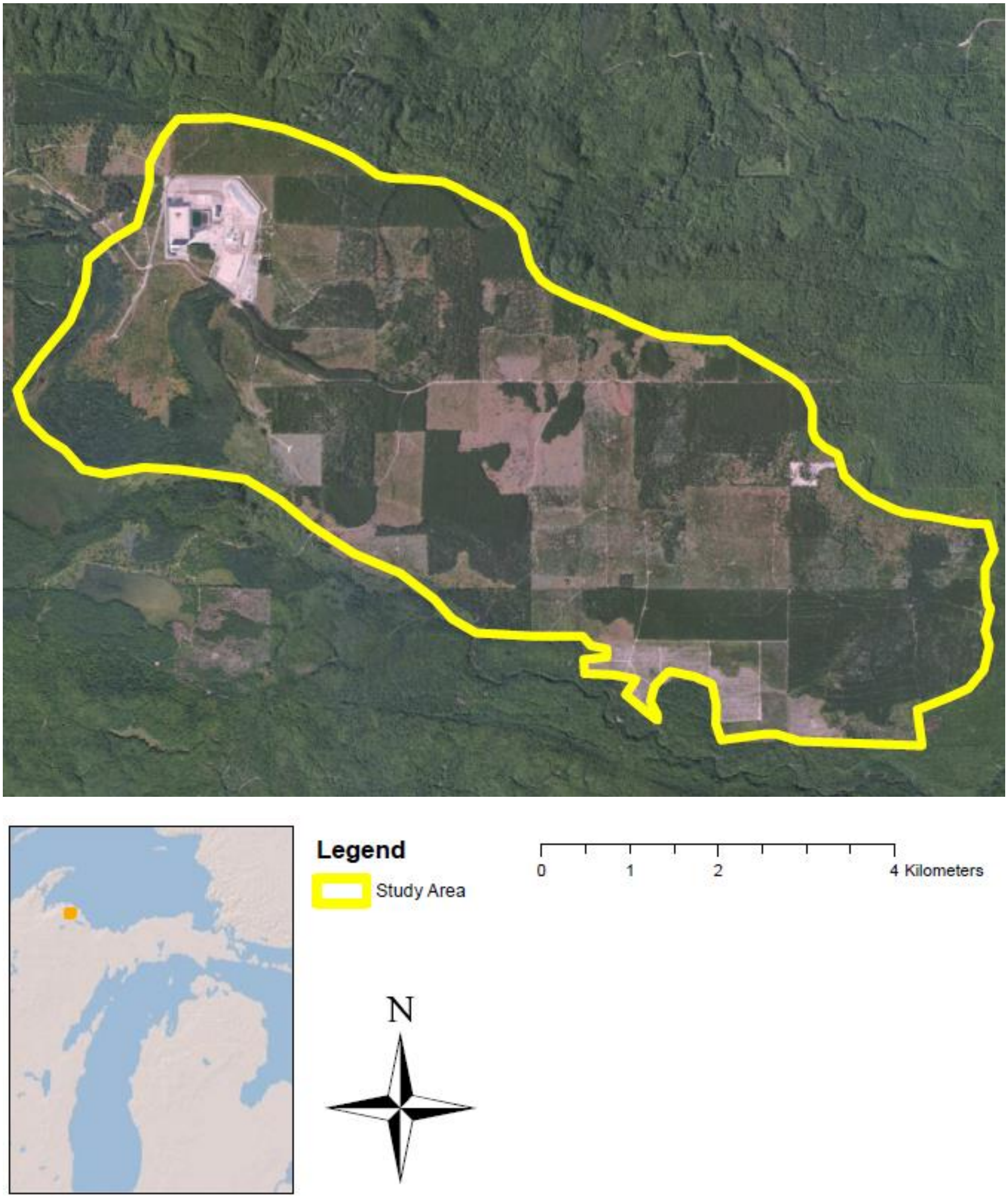
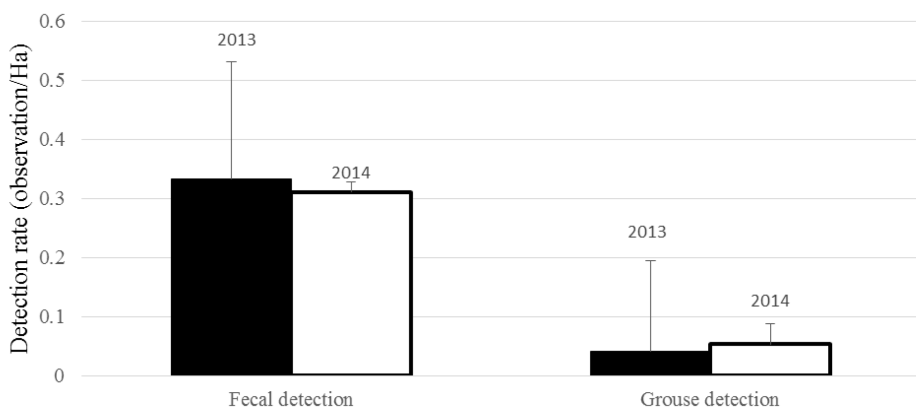


Figure 1.1: Yellow Dog Plains study area in Marquette County, Michigan.



Indicator of grouse presence

Figure 1.2: Detection rates (per ha) of fecal pellets and spruce grouse on the Yellow Dog Plains in Marquette County, Michigan, 2013-2014.

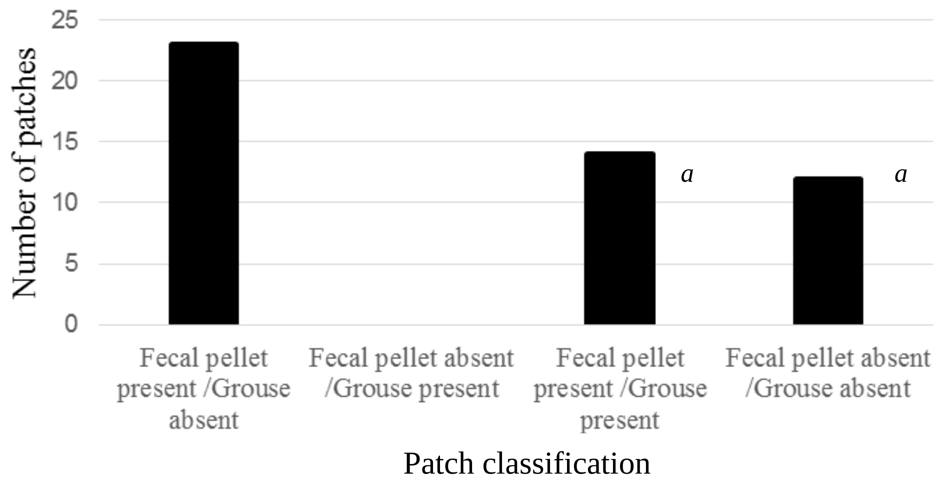


Figure 1.3: Patches classified by presence of spruce grouse on the Yellow Dog Plains in Marquette County, Michigan, 2013-2014 (a= Occupancy indicators in agreement).

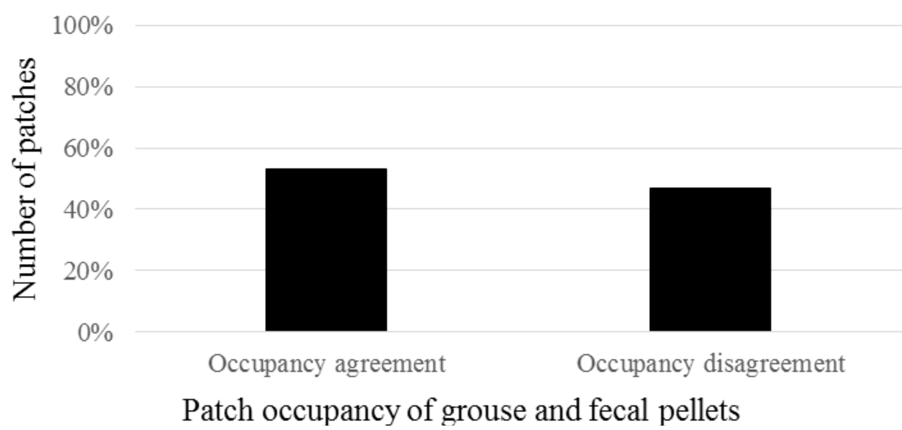


Figure 1.4: Habitat patch occupancy determined by presence of spruce grouse fecal pellets and flush counts on the Yellow Dog Plains in Marquette County, Michigan, 2013-2014.

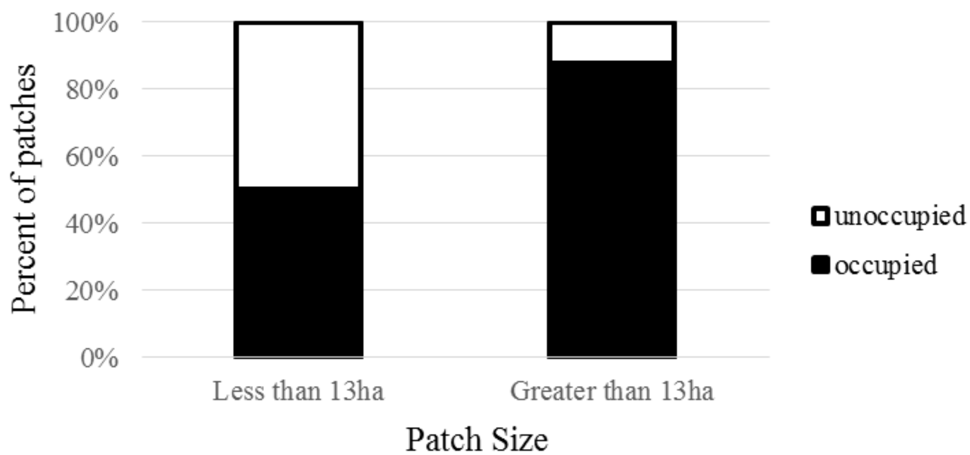


Figure 1.5: Habitat patch occupancy determined by presence of spruce grouse fecal pellets and flush counts on the Yellow Dog Plains in Marquette County, Michigan, 2013-2014.

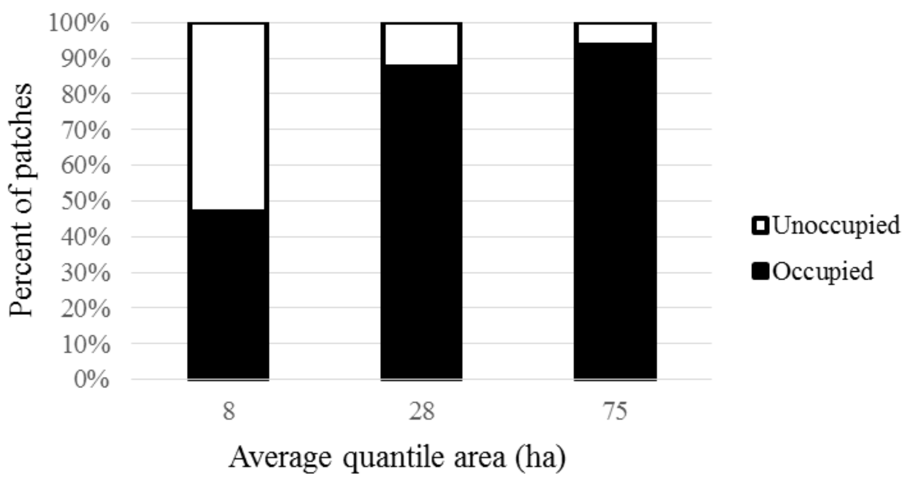


Figure 1.6: Spruce grouse and fecal presence in habitat patches aggregated by patch size, on the Yellow Dog Plains in Marquette County, Michigan, 2013-2014.

Table 1.1: Spruce grouse presence in habitat patches on the Yellow Dog Plains in Marquette County, Michigan, 2013-2014. Habitat patches with grouse and fecal pellet presence or grouse and fecal pellet absence were considered in agreement.

Size Quantile	Mean Patch Size (ha)	N	Occupancy Frequency	Agreement Frequency
1	8	17	0.47	0.59
2	28	16	0.88	0.29
3	75	16	0.94	0.69

Table 1.2: Spruce grouse presence in habitat patches with different complexity on the Yellow Dog Plains in Marquette County, Michigan, 2013-2014. Habitat patches with grouse and fecal pellet presence or grouse and fecal pellet absence were considered in agreement.

Complexity Quantile	Mean Complexity (m/ha)	N	Occupancy Frequency	Agreement Frequency
1	88	17	0.71	0.59
2	141	16	0.75	0.50
3	240	16	0.81	0.50

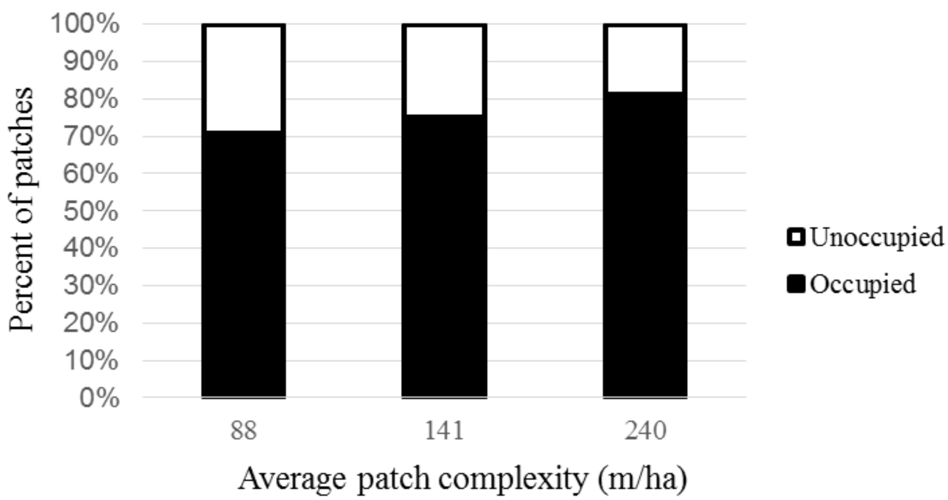


Figure 1.7: Spruce grouse and feces presence in habitat patches aggregated by patch complexity, on the Yellow Dog Plains in Marquette County, Michigan, 2013-2014.

CHAPTER 2

HABITAT USE BY SPRUCE GROUSE ON THE YELLOW DOG PLAINS IN MICHIGAN'S UPPER PENINSULA

ABSTRACT

The spruce grouse (*Falcipennis canadensis*) is listed as a "species of concern" in Michigan and threatened in Wisconsin (MIDNR 2009, WIDNR 2014). In Michigan, spruce grouse are found almost exclusively in the Upper Peninsula. In Marquette County, the Yellow Dog Plains is a favored area for spruce grouse. Typical spruce grouse habitat in Michigan consists of upland jack pine (*Pinus banksiana*) and low-lying spruce (*Picea* spp.) near bogs, generally interspersed with ericaceous shrub cover. The characteristics of spruce grouse habitat are so specific that changes in forest structure may lead to population declines or local extinction. The Yellow Dog Plains is an area where timber harvests, mineral extraction and human recreation frequently occurs. Research is needed to investigate the cumulative effects of forest disturbance on local spruce grouse.

My objective was to describe the structure and composition of habitat used by spruce grouse on the Yellow Dog Plains at the levels of forest patch, and point of presence. I used vegetation cover and composition metrics, as well as measures of patch connectivity, size and complexity to predict habitat use by spruce grouse. Abundance of vertical vegetative cover was greater in patches and points selected by spruce grouse, but canopy cover was less dense in patches and points selected by spruce grouse. Patch level habitat use by spruce grouse on the Yellow Dog Plains was greatly influenced by patch area and canopy density (*Canonical Correlation*^{2}=0.36, df=2, *P*<0.001)

INTRODUCTION

Habitat loss and fragmentation are the two driving causes of global species extinction and declines in biodiversity (Pereira et al. 2010, Rands et al. 2010). A recent long term analysis of global forest cover suggests 70% of remaining forests are within 1 km of forest edge (Haddad et al. 2015). There is an immediate need for action to restore and improve landscape connectivity; however, continued habitat fragmentation is inevitable with expansion of human populations and land modification.

Boreal forests are one of the most extensively forested biomes and are important for timber harvest (Youngblood and Titus 1996). Between 2000 and 2012, global net-loss of boreal forest was second only to that in the tropics (Hansen et al. 2013). Maintaining native species diversity in forest lands is an important objective in wildlife management, especially in areas of timber harvest, mining, and human recreation. Managing habitat for wide-ranging species is challenging; the negative effects of decreasing size and increasing isolation of habitat patches may have profound effects on species of low mobility and high mortality. Spruce grouse (*Falcipennis* spp.) are boreal obligates and may be threatened by forest fragmentation.

The genus *Falcipennis* has a circumpolar distribution and includes two species, spruce grouse and Siberian grouse (*F.canadensis*, and *F. falcipennis*), both of which occupy boreal forests (Boag and Schroeder 1992, Andreev 2001). In North America, spruce grouse (*F. canadensis*) are widely distributed across the northern United States and Canada and their range extends from Alaska to Labrador, across the northwestern states of the U.S. and south into New England (Boag and Schroeder 1992, Williamson et al. 2008). Their relatively large body size, sedentary lifestyle, and ability to capitalize on abundant, but nutrient poor resources allows spruce grouse to flourish in a relatively harsh environment.

Spruce grouse habitat varies across their geographic range (Jonkel and Greer 1963, Robinson 1969, Ratti et al. 1984, Allan 1985, Schroeder and Boag 1991, Anich et al. 2013a). For example, the Prince of Wales spruce grouse (*F.c. isleibi*) in southeast Alaska occupies a temperate rainforest ecosystem, whereas spruce grouse in the northern and central reaches of their range occupy lodgepole pine (*Pinus contorta*) stands (Russell 1999, Schroeder and Boag 1991). Spruce grouse in the eastern portions of their geographic range occupy boreal ecotypes including old-growth spruce (*Picea* spp.) and tamarack (*Larix laricina*) bogs, black and white spruce (*P. mariana* and *P. glance*, respectively) stands, as well as jack pine stands (*Pinus banksiana*) (Robinson 1969, Allan 1985, Anich et al. 2013a). In the Northeastern portions of their range, highest densities of spruce grouse are found in large, even-aged stands of fire-sere ecosystems (Keppie 1997 as cited in Russell 1999). In all regions of their range, spruce grouse require specific, small-scale, habitat characteristics.

In the Midwest region of their range, spruce grouse often occupy islands of conifer stands resulting from fragmentation by human activity (Robinson 1980). Important forest types used by Midwestern spruce grouse include the ecotones around bogs with low-lying black spruce and tamarack, cedar forests (*Thuja occidentalis*), upland jack pine and areas rich with ericaceous shrubs (Anich et al. 2013a, Schroeder and Boag 1991). Near Mio, Michigan, spruce grouse were observed in jack pine stands >15 years old that had been burned for the Kirtland's warbler (*Setophaga kirtlandii*) (Phil Hubinger and Kim Piccolo, U.S. Forest Service, February, 2015, personal communication). Since 2000, spruce grouse have been found occasionally in the Mack Lake Fire area (burned in 1980). They are believed to occur in small numbers in areas across the Mio Ranger District (Kim Piccolo, U.S. Forest Service June, 2015, personal communication).

In addition to local specificity, spruce grouse microhabitat varies seasonally (Robinson 1969, Pietz and Tester 1982, Anich et al. 2013a). For example, territorial males prefer areas with greater canopy cover, but less vertical cover than other, non-breeding, males (McLachlin 1970). Nesting females prefer wetland areas with high overall concealment in relation to other times of the year (Anich et al. 2013b). In the winter, male and female spruce grouse move from relatively open stands into denser forested stands (Robinson 1980, Allan 1985, multiple sources in Boag and Schroeder 1992). Lack of these specific microhabitats may be limiting to local spruce grouse populations (Boag and Schroeder 1992, Potvin and Courtois 2006) and this poses a conservation concern, especially for populations in areas of monoculture timber stands.

Spruce grouse are listed as a species of concern in Michigan and New Hampshire, threatened in Wisconsin, and endangered in New York (Williamson et al. 2008, Michigan Department of Natural Resources 2009, Wisconsin Department of Natural Resources 2014). Spruce grouse are still relatively common in the northern portions of their range, but habitat loss and range contraction has been observed in southern reaches (multiple sources in Storch 2007). Spruce grouse habitat may be threatened by continued loss of connected and structurally complex forests. Habitat degradation and small population sizes are principal threats to spruce grouse (multiple sources in Storch 2007).

Spruce grouse were once common in Michigan, but their numbers reportedly decreased by 1912 (Ammann 1963). They have been protected since 1915. Despite protection, the status of spruce grouse populations is unknown in Michigan. I focused on a population of spruce grouse near the southern edge of their range in northern Michigan. The overarching goal of this research was to understand habitat use by spruce grouse in relation to forest patch structure, composition, and context on the landscape. In this study “habitat” is defined as areas where vegetation composition and structure are similar to that reported in the literature as spruce grouse habitat, or where I found spruce grouse or spruce grouse fecal pellets.

My objective was to describe the structure and composition of habitat used by spruce grouse on the Yellow Dog Plains, Marquette County, Michigan at the levels of forest patch, and point of presence.

STUDY AREA

The Yellow Dog Plains (YDP) study area is located in northern Marquette County, Michigan. State forest covers about 1538 ha in scattered parcels. The study area is dominated by jack pine cover and additional cover types include northern hardwood, white pine, upland open/semi-open lands, lowland open/semi-open lands (MIDNR 2012). This area was selected for research because spruce grouse have been previously studied on the YDP (Robinson 1969), providing an opportunity to compare the status of habitat use in the same area 45 years later. Forests on the YDP have been heavily harvested since the late 1800's (Rydholm 1989) and a patchwork pattern is evident in aerial photos (Figure 2.1). The timber harvest rotation drives turnover of spruce grouse habitat on the YDP. Since Robinson's (1969, 1980) research the YDP has become increasingly fragmented and the proportion of high quality spruce grouse habitat has declined (Hill 2015, Chapter 3). Although the landscape has changed, adequate quality habitat persists and the YDP remains a stronghold for spruce grouse.

METHODS

Habitat Use Surveys

I searched for spruce grouse on the YDP beginning surveys from about 0800 and ending at approximately 1600, May to September 2013 and 2014. My survey times and season were similar to Robinson (1980). I searched for spruce grouse using a variation of Robinson's (1980) method. I walked transects oriented north to south and spaced about 150 m apart at a slow pace. In contrast to Robinson's (1980) method, I searched for spruce grouse alone and did not use a flushing dog.

Habitat needs of spruce grouse change throughout the year, and I was unable to resurvey the YDP seasonally. To address this weakness, I reversed the geographic order each year. In 2013, I walked transects while working my way eastward in the study area and walked transects while working my way westward in the study area in 2014. A study point was designated at each observation of grouse or grouse feces. Fibrous grouse pellets stay intact for a month to several months (Evans 2007). Because of this, it is possible that habitat patches and points that had not been used by spruce grouse for several weeks were still classified as used.

I collected data along each transect in a random-systematic fashion. The first sample point on each transect was randomly selected using a random number generator (ranging from 0 to 150 m) and subsequent points were spaced every 150 m. Additional points were designated where spruce grouse or their fecal pellets were detected. These points marked the center of 400 m^2 circular plots in which all data were collected.

I also searched for fecal pellets during a 3-minute designated search interval in each 400 m^2 plot. Spruce grouse detection locations and fecal pellet counts were used as indices of habitat use. If more than one grouse or pellet group was observed within a 400 m^2 circular area of each other, the observations were considered related and only the location of the first observation was sampled (i.e. two or more birds were considered as one observation). Fecal pellets were identified by size and composition.

Vegetation Surveys

I conducted vegetation surveys while simultaneously searching for spruce grouse. Vegetation data were collected in 400 m^2 circular plots, at each study point. To minimize disturbance to grouse, upon detection, I recorded the observation location and returned to collect vegetation data at a later time. I recorded habitat structure and composition, and used the point-centered quarter method in each plot to determine the importance value of tree species in each classified habitat patch (Cottam and Curtis 1956, Mitchell 2007). Importance values were calculated using a combination of relative density, relative size, and relative frequency of tree species (Mitchell 2007). In each plot, I classified the 3-dimensional vegetation community using the Relevè method to determine the abundance of species, life form groups (i.e. deciduous, coniferous, forb), and height classes (Minnesota Department of Natural Resources 2007).

Two methods were used to measure horizontal and vertical vegetative cover and density at each study point. I used a hand-held densitometer (convex model A, Forestry Suppliers spherical crown densitometer) to record upper canopy density in 4 cardinal directions at each point. I also used a 2 m Nudds vegetation profile board (Nudds 1977) to estimate horizontal vegetative density and visual obstruction on the landscape at 0 to 0.3 m, 0.3 to 0.6 m, 0.6 to 0.9 m, 0.9 to 1.3 m, 1.3 to 1.6 m 1.6 to 2 m.

Landscape Measurements

I created a digital habitat map of the study area with information from 1:10,000 m-scale 2012 digital satellite imagery. Habitat patches were delineated based on contiguity of continuous vegetation using satellite imagery (ESRI 2011) and ArcGIS 10.1. ArcGIS was used to calculate distance metrics including shortest distance from observation to patch edge. I converted habitat patches into raster format to use in landscape analysis in FRAGSTATS (v4.2.1.603, McGarigal and Ene 2013).

I used 5 metrics to classify habitat patches including measures of patch area, extent, and complexity. Radius of gyration is a patch-based metric representing patch extent. It reflects both patch size and compaction and is calculated using the mean distance between each 5 m^2 cell (pixel) in the designated patch and the patch centroid. I measured patch complexity using perimeter-area ratio and a patch-based contiguity index (LaGro 1991). The contiguity index is similar to perimeter-area ratio because it reflects patch shape, but it focuses specifically on patch compaction and elongatedness.

I used 2012 digital satellite imagery and ArcGIS to calculate patch area. Lastly, I used core area to reflect the area of habitat patch, based on my measured spatial patterns of grouse presence. To determine effective core area for grouse, I measured the distance between closest occupancy points and nearest edge for each habitat patch (Figure 2.2). Mean distances represented the distance of edge effect and was used to calculate core area for each patch.

Statistical Analyses

Frequency of grouse and fecal pellet occurrence in patches sampled in 2013 and in 2014 were compared to determine if habitat use by spruce grouse changed over the course of this study (Hill 2015, Chapter 1). Frequencies were similar in both years and were grouped for statistical analyses. Fecal pellets are a reliable indicator of general habitat use by spruce grouse, and therefore I used both fecal pellets and grouse observations to classify patches and points as used and unused (Hill 2015, Chapter 1).

Patch-level analyses.—I used ArcGIS and IBM SPSS Statistics 21.0 to summarize the vegetative composition and density, tree species importance values, grouse and grouse feces observation points, and spatial metrics for all delineated habitat patches. I used discriminant analysis to test for differences between patches used by spruce grouse and those unused when all variables were considered simultaneously. I removed variables to eliminate multicollinearity and used a stepwise discriminant function analysis stepwise to create a predictor model (Table 2.1). I used results from previous habitat studies to inform my hypotheses for predictor variables in the discriminant function analysis at the patch level (Ellison 1966, Robinson 1980, Anich et al. 2013a).

Point-level analyses.—I used ArcGIS and IBM SPSS Statistics 21.0 to summarize the vegetative composition and density at points where grouse or grouse feces were observed, and at random points when all variables were considered simultaneously. I used discriminant analysis to test for differences between random-systematic and non-random points when all variables were considered simultaneously. I removed variables to eliminate multicollinearity and used a stepwise discriminant function analysis stepwise to create a predictor model (Table 2.1). I used results from previous habitat studies to inform my hypotheses for predictor variables in the discriminant function analysis at the point level (Ellison 1966, Robinson 1980, Anich et al. 2013a).

RESULTS

I detected grouse on 28% of delineated habitat patches and independent observations ranged from 0 to 8 grouse per patch. I detected fecal pellets on 75% of forest patches and independent observations ranged from 0 to 58 per patch. Seventy-three percent of surveyed habitat patches were used by spruce grouse.

Patch-level analyses

Vegetative cover and density varied between patches used and unused by spruce grouse, based upon a discriminant function analysis where all variables were considered simultaneously. Average canopy cover was greater in habitat patches not used by spruce grouse (Table 2.1, $P<0.001$). In contrast, vertical vegetative cover and visual obstruction between 0 and 2 m was greater in habitat patches used by grouse (P= 0.013, 0.001, 0.005, 0.006, 0.005, 0.052, respectively for all coverboard comparisons).

Jack pine was the dominant tree species for all sampled habitat patches, and had the highest importance value in patches used by spruce grouse (Table 2.1, P=0.075, based upon discriminant analyses). Balsam fir was the only other tree with significantly higher importance values in patches used by spruce grouse (Table 2.1, P=0.049).

Abundance of plant cover at specific height classes was relatively similar between patch types (Table 2.1). Evergreen species 5 to 10 m tall were more abundant in patches used by spruce grouse (P= 0.057) than in unused patches. As expected because of the sample approach, deciduous cover was minimal in all patches. Grouse used patches where deciduous species were less abundant 0.5 to 5 m above ground (P= 0.020 and 0.52, respectively). Moss and lichen were about 20% more abundant in patches used by spruce grouse (P=0.079) than in unused patches. Graminoids were about 23% less abundant in used patches (P=0.054) than in unused patches. No other ground cover classes differed between patch types.

Patches used by spruce grouse were larger than unused patches (Table 2.1, P=0.001, discriminant analysis where all variables were considered simultaneously). Core area, radius of gyration, perimeter-to-area ratio, and contiguity metrics were not different between patch types.

Although core area did not differ between patch types, one occupied patch was less than 37 m in width and was eliminated when a buffer distance was applied.

Patch-level habitat model

I used a stepwise discriminant function analysis to create a predictor model of spruce grouse presence at the patch level. Several predictor variables were correlated and this violated one of the key assumptions of discriminant function analysis. All tree importance values were eliminated because they were correlated with cover class values and canopy density.

The predictor model contained two of the nineteen predictors (Table 2.1). Canopy density and patch area correctly predicted spruce grouse presence at the patch level 85% of the time (Table 2.2, canonical correlation^2 =0.43, *P*=0.001). Of the 7 misclassified patches, 2 were used and 5 were unused by spruce grouse.

Point-level analyses

Vertical vegetative cover and topographical obstruction was greater at points used by spruce grouse, than at random-systematic points (Table 2.3, *P*<0.021 for all coverboard comparisons). Similar to patch analyses, canopy cover was less dense at points used by spruce grouse, than random-systematic points (Table 2.3, *P*<0.001).

Evergreen cover between 0.1 and 0.5 m, 5 to 10 m, and 10 to 20 m was greater at points used by grouse than random points (Table 2.3, *P*=0.021, 0.004, and 0.021, respectively). All other height classes of evergreen cover failed to reject the null hypothesis that evergreen cover does not differ between points used and unused by spruce grouse. Similar to patch-based analyses, deciduous cover did not differ between random-systematic and nonrandom points.

Graminoid cover was less abundant at points with grouse occurrence than at random points by about 10% (Table 2.3, *P*<0.001). Moss and lichen cover was greater at points with grouse occurrence, supporting similar results from patch-based analyses (P= 0.007). No other differences were found in ground cover with respect to patch types.

Point-level habitat model

I used a stepwise discriminant function analysis to create a predictor model of spruce grouse presence at the point level. Four out of 14 predictor variables were used in the habitat model (Table 2.3). Canopy density, evergreen cover 7 to 8 m high, moss and lichen cover, and vertical vegetative density correctly predicted spruce grouse presence at the point level 69% of the time (Table 2.2, canonical correlation^2 =0.10, P=0.001). Of the 189 misclassified patches, 151 were used and 38 were unused by spruce grouse.

DISCUSSION

Spruce grouse are secretive birds, and were a challenge to locate on the Yellow Dog Plains. Fecal pellet observations used in addition to direct observations of grouse (i.e. flushing birds) provided substantially more evidence for grouse presence than direct observation alone. To my knowledge, this approach has not been used to describe large-scale habitat use by spruce grouse and fecal pellets seem to be a reliable way to detect general habitat use (Hill 2015, Chapter 1).

My study area was a homogenous forest community, and I found many similarities between variables describing used and unused patches. For example, only one height class of evergreen vegetation differed between patch types. Evergreen vegetation dominated the study area and coniferous trees had the highest importance values on the YDP. Although the study area is generally a monoculture of jack pine, I believe that the presence of dense evergreens 5 to 10 m high may be biologically important to spruce grouse. Importance of understory density to spruce grouse is well documented in the literature and my results support these reports (Boag and Schroeder 1992).

Vegetation and cover variables of associated use categories were similar in comparisons between patch and point based levels. However, I did not expect to find grouse use in areas of relatively open canopy. Prior studies report dense canopy cover to be an important variable in spruce grouse habitat (multiple citations in Boag and Schroeder 1992). My findings may be attributed to seasonal differences in habitat use. In summer months spruce grouse diet is largely composed of *Vaccinium* spp., and these plants are relatively shade intolerant (Ellison 1966, Humbert et al. 2007). Although dense canopy cover may be necessary at the patch level, small openings in canopy cover may be important for forage in summer months.

Vegetative ground cover included a diversity of flowering plants and by grouping edible and inedible plants into a single cover classification I may have masked or diluted the importance of ground cover for summer forage. The moss and lichen cover class is mostly composed of edible species and was more abundant in areas used by spruce grouse. Ellison (1966) found moss sporophytes and stems in 20% of sampled spruce grouse crops in July-August and 14% during September and October in Alaska. Future research will require a species-level focus on ground cover to find effects on small-scale habitat use by spruce grouse.

Patch area was the only patch metric that differed between used and unused patches. These results contradict my prediction that patch complexity, edge, and connectivity are important for habitat use by spruce grouse. Spruce grouse are habitat specialists and unnatural, abrupt, edges likely have a negative effect on population dynamics (Boag and Schroeder 1992, Devictor et al. 2008).

Potvin and Courtois (2006) found spruce grouse in residual forest strips in large clearcut boreal forests in southcentral Quebec. The persisting spruce grouse population occurred in forest strips ranging from 60 to100 m in width. Potvin and Courtois' findings, and my results, bring into question the effect of habitat fragmentation on spruce grouse. Possibly, spruce grouse do not avoid unnatural edges and small habitat fragments, despite negative effects. Or perhaps their relatively sedentary behavior keeps them from dispersing to larger habitat patches after a clearcut. Patch metrics in my study do not measure the quality of surrounding habitat and this may be reflected in the seeming lack of effect of edge on grouse habitat use.

Habitat variables successfully predicted patch use by grouse 94% of the time. Cross-validated patches used by spruce grouse were predicted correctly more often than unused patches. Unused patches were incorrectly classified as used by spruce grouse 39% of the time.

The point level habitat model had a low success rate during cross-validation. Only 69% of cross-validated points were correctly classified, and most of the successes were in predicting unused points. In addition 79% of the misclassifications resulted in type I errors. This model uses vegetative abundance measures at the scale of life form and height class. Predictive variables with a small scale focus may have yielded a more accurate model.

MANAGEMENT IMPLICATIONS

Jack pine was the most abundant overstory species on the YDP and grouse were found in patches with dense evergreen vegetative cover 0 to 2 m high. Thus, it is important to consider density of understory cover on timber lands when managing for spruce grouse. Overall canopy should provide about 40% cover, but it may be important to have slight variation to support growth of species important for summer forage.

In addition to these patch-level considerations, forest management should produce a locally diverse landscape to support spruce grouse throughout their entire life cycle. This can be accomplished by maintaining early, mid, and late successional stands on the landscape. Thus, as a stand comes into harvest age, adequate spruce grouse habitat remains.

Lastly, forest patch area over 40 ha is important for grouse use. My results suggest that grouse use contiguous forest stands averaging 40 ha, and smaller stands of similar habitat are unused (Table 2.1 P=0.001). Although unnatural edges and patch complexity do not seem to deter habitat use, I suggest a conservative approach to forest management because spruce grouse on the YDP may not travel to larger residual patches that better support their needs.

TABLES AND FIGURES

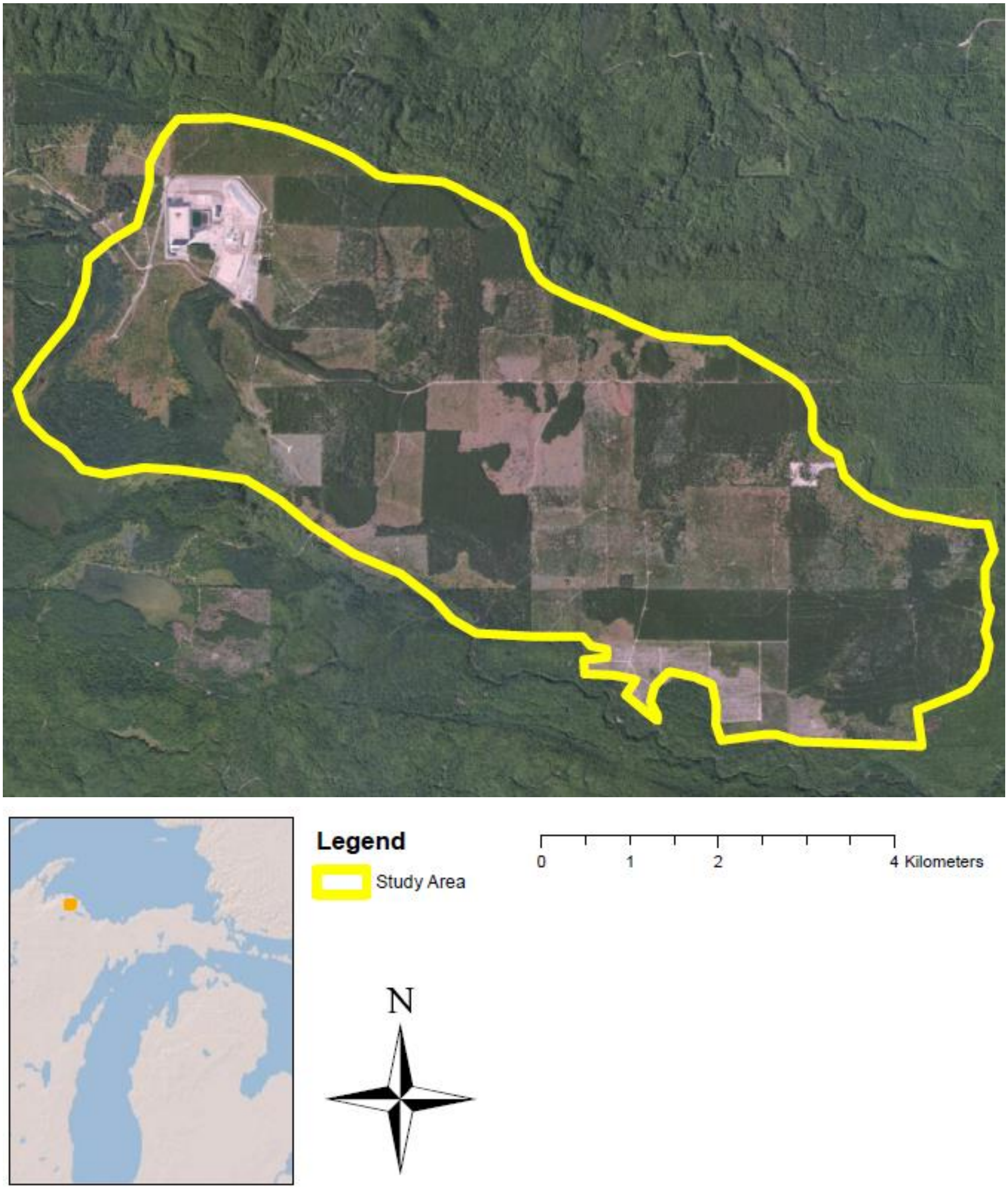


Figure 2.1: Yellow Dog Plains study area in Marquette County, Michigan.

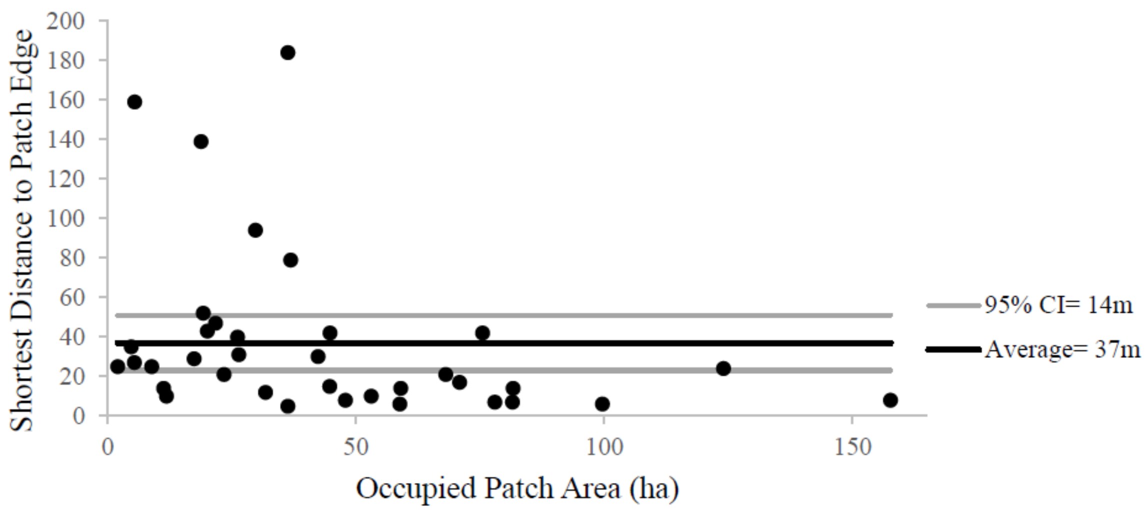


Figure 2.2: Shortest distance to edge and closest occupied point in each habitat patch used by spruce grouse on the Yellow Dog Plains, Marquette County, Michigan, 2013-2014.

Table 2.1: Vegetative density and composition, and patch metrics summarized for habitat patches on the Yellow Dog Plains, Marquette County, Michigan, 2013-2014 (*used in stepwise analysis).

	Measurement	**Used Patches (*n*= 36)** $\bar{x}$	**Used Patches (*n*= 36)** 95% CI	**Unused Patches (*n*= 13)** $\bar{x}$	**Unused Patches (*n*= 13)** 95% CI	**F**	***P***
	Vegetation density (% cover)						
*	Average Canopy Cover	39.82	7.81	72.72	15.61	16.087	<0.001
	0-0.3 m coverboard	44.55	0.14	31.74	9.08	6.668	0.013
	0.3-0.6 m coverboard	40.14	6.37	25.70	6.58	13.581	0.001
	0.6-0.9 m coverboard	37.57	7.84	25.94	6.70	8.604	0.005
*	0.9-1.3 m coverboard	39.54	10.71	28.00	7.62	8.367	0.006
	1.3-1.6 m coverboard	42.07	8.94	29.42	9.45	8.831	0.005
	1.6-2.0 m coverboard	45.70	3.15	35.67	12.02	3.970	0.052
	Importance value						
	Abies balsamea	3.00	1.64	0.96	1.82	4.075	0.049
	Acer rubrum	3.83	1.38	11.69	13.78	0.997	0.323
	Acer saccharum	0.11	0.22	0.00		0.320	0.574
	Amelanchier spp.	0.53	0.75	0.00		1.392	0.244
	Betula alleghaniensis	0.07	0.14	0.00		0.320	0.574
	Betula papyifera	2.24	1.75	0.00		4.757	0.340
	Larix laricina	2.83	1.77	6.52	7.61	0.892	0.354
	Pica glauca	5.15	2.96	5.49	8.09	1.266	0.266

	Pica mariana	14.43	10.94	15.21	20.08	1.933	0.171
	Pinus banksiana	221.68	26.49	139.79	67.55	3.319	0.075
	Pinus resinosa	27.94	18.60	34.87	36.37	1.781	0.188
	Pinus strobus	12.76	6.52	30.66	34.46	1.102	0.299
	Populus tremuloides	1.01		2.08	1.89	0.032	0.859
	Prunus serotina	4.38	2.08	7.48	6.87	0.072	0.790
	Quercus rubra	1.50	1.63	0.00		1.792	0.187
	Cover class (% cover)						
*	Needleleaf evergreen 0.0-0.1 m	0.12	0.14	0.00		2.138	0.151
*	Needleleaf evergreen 0.1-0.5 m	0.18	0.20	1.61	2.83	0.756	0.389
*	Needleleaf evergreen 0.5-2 m	8.92	6.37	16.42	11.59	0.296	0.589
*	Needleleaf evergreen 2-5 m	11.46	7.84	5.61	4.09	0.044	0.835
*	Needleleaf evergreen 5-10 m	37.01	10.71	22.71	13.88	3.807	0.057
	Needleleaf evergreen 10-20 m	18.46	8.94	10.55	13.94	2.758	0.104
*	Needleleaf evergreen 20-35 m	1.94	3.15	1.64	2.16	0.002	0.969
	Broadleaf deciduous 0.0-0.1 m	1.80	1.23	3.31	3.76	0.432	0.514
*	Broadleaf deciduous 0.1-0.5 m	1.70	1.17	1.44	1.40	1.249	0.270
*	Broadleaf deciduous 0.5-2 m	5.05	2.41	14.63	5.96	5.859	0.020
*	Broadleaf deciduous 2-5 m	6.53	2.64	5.40	6.43	3.987	0.052
*	Broadleaf deciduous 5-10 m	3.17	2.09	6.18	6.31	2.483	0.122
*	Broadleaf deciduous 10-20 m	0.01	0.02	0.00		2.652	0.110

*	Ferns	44.63	10.30	35.36	21.10	0.018	0.894
*	Moss and lichen	45.08	8.10	26.66	8.44	3.229	0.079
	Graminoids	12.92	3.94	35.63	15.74	3.902	0.054
*	Vegetative groundcover 0.0-0.1 m	54.44	6.95	58.20	13.56	0.962	0.332
*	Abiotic groundcover	28.51	7.11	37.60	15.87	0.995	0.626
	Patch metrics						
*	Area (ha)	43.34	11.51	15.45	7.47	12.027	0.001
	Core area (ha)	24.54	8.10	33.23	19.38	0.129	0.721
*	Radius of gyration (m)	248.25	41.62	303.44	86.35	0.618	0.436
	Perimeter:Area (m/ha)	162.35	24.51	137.68	34.72	0.165	0.687
	Contiguity	0.98	>0.01	0.98	>0.01	0.640	0.801

Table 2.2: Cross validation of patch and point level habitat models predicting spruce grouse habitat use on the Yellow Dog Plains, Marquette County, Michigan, 2013-2014.

	Percent Correctly Classified			Summary of Canonical Discriminant Functions	
	Used	Unused	Total	*Canonical correlation*^{2}	*P*
Patch level	94%	62%	85%	0.36	<0.001
Point level	21%	91%	69%	0.10	<0.001

Table 2.3: Vegetative density and composition summarized for points on the Yellow Dog Plains, Marquette County, Michigan, 2013-2014. Points are classified as “used” and “unused” by spruce grouse with presence of grouse or grouse fecal pellets (*used in stepwise analysis).

		Used Points (*n*=295)		**Unused Points (*n*=561)**			
	Measurement	$\bar{x}$	**95% CI**	$\bar{x}$	**95% CI**	**F**	***P***
	Vegetation density (% cover)						
*	Average Canopy Cover	28.10	3.76	48.30	3.22	34.899	<0.001
	0-0.3 m coverboard	51.97	2.77	45.22	2.18	6.396	.021
	0.3-0.6 m coverboard	46.50	2.66	38.53	2.01	14.803	.001
	0.6-0.9 m coverboard	42.14	2.73	35.45	1.83	11.822	.003
*	0.9-1.3 m coverboard	44.94	2.69	36.03	1.80	20.150	.000
	1.3-1.6 m coverboard	44.28	2.48	38.27	1.94	11.693	.011
	1.6-2.0 m coverboard	47.60	2.62	41.68	2.10	10.726	.012
	Cover class (% cover)						
*	Needleleaf evergreen 0.0-0.1 m	0.23	0.21	0.30	0.36	0.453	.793
*	Needleleaf evergreen 0.1-0.5 m	0.23	0.21	1.20	0.48	6.173	.021
*	Needleleaf evergreen 0.5-2 m	8.58	2.60	9.08	1.65	1.944	.964
*	Needleleaf evergreen 2-5 m	16.03	3.45	11.25	1.91	1.760	.092
	Needleleaf evergreen 5-10 m	36.80	4.60	29.71	2.97	2.201	.004
	Needleleaf evergreen 10-20 m	15.65	3.60	9.99	2.13	0.993	.021
*	Needleleaf evergreen 20-35 m	1.78	1.41	3.96	1.30	4.527	.081
*	Broadleaf deciduous 0.0-0.1 m	2.26	0.86	1.79	0.66	1.200	.624
*	Broadleaf deciduous 0.1-0.5 m	0.95	0.48	1.83	0.54	3.184	.064
	Broadleaf deciduous 0.5-2 m	4.05	1.00	7.04	1.16	5.934	.018

	Broadleaf deciduous 2-5 m	7.81	1.41	7.62	1.16	0.822	.966
*	Broadleaf deciduous 5-10 m	2.32	1.04	4.51	1.13	6.657	.119
*	Broadleaf deciduous 10-20 m	0.08	0.12	0.17	0.13	0.586	.422
	Ferns	46.269	4.379	46.743	3.289	0.225	.464
*	Moss and lichen	46.358	3.596	39.598	2.579	6.050	.022
	Graminoids	11.650	1.852	22.678	2.410	12.649	.000
*	Vegetative groundcover 0.0-0.1 m	56.270	3.446	60.585	2.486	3.432	.017
*	Abiotic groundcover	30.662	3.660	30.388	2.750	0.283	.503

CHAPTER 3

THE INFLUENCE OF LAND COVER CHANGE ON SPRUCE GROUSE HABITAT OVER 77 YEARS IN NORTHERN MICHIGAN

ABSTRACT

The rapidly growing human population has increasing consumptive demands that drive habitat loss and fragmentation. Boreal forests are one of the most extensively forested ecotypes and are important for forest products, especially in Michigan's Upper Peninsula (Potter-Witter 1995, Youngblood and Titus 1996, Smith et al. 2000). Fragmentation and turnover of forest stands by timber harvest surely influence distribution and quality of habitat for boreal obligate species.

I analyzed historical aerial photography to measure landscape change over 77 years and investigate habitat change for a local population of spruce grouse (*Falcipennis canadensis*). I created an index to habitat quality using a combination of patch size, forest stand age, and density as interpreted from historical aerial imagery. My results show that the Yellow Dog Plains in Marquette County, Michigan, have become increasingly fragmented since 1937 and high quality spruce grouse habitat decreased, being replaced by intermediate quality habitat.

INTRODUCTION

Habitat loss and fragmentation are the two driving causes of global species extinction and declines in biodiversity (Pereira et al. 2010, Rands et al. 2010). A recent long-term analysis of global forest cover suggests 70% of remaining forests are within 1 km of forest edge (Haddad et al. 2015). There is an immediate need for action to restore and improve landscape connectivity; however, continued habitat fragmentation is inevitable with expansion of human populations and land modification. Effective and long-lasting conservation efforts should consider the resource needs and local economy.

Boreal forests are one of the most extensive forested biomes and are important for timber harvest (Youngblood and Titus 1996, Smith et al. 2000). Hansen et al. (2013) found global loss of boreal forest was second only to that in the tropics from 2000 to 2012. Forest harvest for timber products are an important part of Michigan history and the economy, especially in the Upper Peninsula (Potter-Witter 1995).

Maintaining native species diversity in forest lands is an important objective in wildlife management, especially in areas of timber harvest, mining, and human recreation. Managing habitat for broadly distributed species is challenging; the negative effects of decreasing size and increasing isolation of habitat patches may have profound effects on species of low mobility and high mortality. In the Upper Peninsula of Michigan, spruce grouse (*Falcipennis canadensis*) habitat may be affected by increases in resource extraction and infrastructure.

The spruce grouse is a boreal obligate species and has been protected in Michigan since 1915 (Ammann 1963, Mccormick and Corace 2011). In Michigan, spruce grouse occur mostly in stands of upland jack pine (*Pinus banksiana*) and low-lying spruce (*Picea* spp.) near bogs, generally interspersed with ericaceous shrub cover (Robinson 1980). Stand age is also an important consideration for spruce grouse habitat. In jack pine and red pine (*Pinus resinsosa*) forests, spruce grouse are found in young to mid-successional stands about 15-30 years old (Boag and Schroeder 1992). In northern Wisconsin and Michigan's Upper Peninsula, spruce grouse have also been found in wetland stands of black spruce (*Picea mariana*) and tamarack (*Larix laricina*) >90 years old (Anich et al. 2014a, Hill 2015). Harvest practices that fail to maintain stand age and structure favored by spruce grouse may lead to population declines or local extinction.

Spruce grouse are at the southern margin of their range in Michigan, where habitat may be patchier and influenced by global climate change (Bouta and Chambers 1990). Climate change models predict microhabitats (ecotones around bogs with low-lying black spruce and tamarack) used by spruce grouse will recede northwards and disappear from the Upper Peninsula during the next 100 years (Prasad et al. 2007). Although remnant populations of spruce may persist for periods greater than 100 years, the disappearance of habitat supporting black spruce will negatively affect regeneration of persisting stands. However, more immediate threats involve timber harvest practices that do not maintain adequate spruce grouse habitat, and fragmentation of existing habitats (Storch 2000, Williamson et al. 2008).

The loss and fragmentation of boreal forest is a formidable detriment to many species across the globe (Balmford et al. 2003). With rapid loss of forests and increase in resource exploitation, the focus of research and policy has turned to conservation biology (Ewers et al. 2010). Managing forests to benefit a suite of species is efficient and realistic in this time of emergency. However, research shows a diversity of changes to ecological processes and species in response to landscape level habitat loss and fragmentation (Prugh et al. 2008).

Betts et al. (2014) suggested habitat loss at the scale of an individual's territory or home range cumulatively has the most direct effect on the individual. However, response to landscape change at scales beyond the individual's territory or home range can vary depending on species. For this reason, a species-centered approach to landscape-level research may be necessary to better understand the impacts of fragmentation in certain systems.

I took a spruce grouse-centered perspective to analyze historical aerial photographs and satellite imagery to measure landscape change and discuss the implications for a local population of grouse. I undertook this study to determine how the land cover of the Yellow Dog Plains varied since 1937 and to use that information to predict the variation in the quality of spruce grouse habitat present.

STUDY AREA

The Yellow Dog Plains (YDP) study area is located in northern Marquette County, Michigan (Figure 3.1). The entire area is located on a flat, glacial moraine about 110 m above sea level. Dominant tree species include black spruce, white spruce (*Picea glauca*), red pine, and white pine (*Pinus strobus*), but mostly jack pine. Additional cover types include northern hardwood, upland open/semi-open lands, and lowland open/semi-open lands (MIDNR 2012).

The YDP exists as a mosaic of several different patch types, and the variation from one patch to the next is abrupt due to harvest practices for timber products. An aerial view shows a patchwork pattern imprinted on the landscape by timber harvest. Although the change from one patch to the next is abrupt, habitat patches on the YDP do not exist in a matrix of uniformly hostile conditions. Instead, the YDP is composed of a variety of patch types that vary in quality for spruce grouse (Figure 3.2).

METHODS

This project was conducted as part of a larger study investigating habitat use by spruce grouse on the Yellow Dog Plains. During the overarching study I collected vegetation data and described forest patches using several methods (Hill 2015, Chapter 2). My time observing forest structure on the ground and referencing patches to recent satellite imagery helped inform interpretation of historical aerial photography.

Landscape Delineation

I delineated habitat patches based on contiguity of continuous vegetation using satellite imagery and historical aerial photography. The Environmental Systems Research Institute’s online database provided 2011 satellite imagery of the Yellow Dog Plains. The Michigan Department of Natural Resources provided aerial photography from 1987, 1978, and 1967 for photocopying and analysis. Photographs from 1937 were obtained through Michigan State University's Aerial Image Archive. I georeferenced imagery using ArcGIS software 10.1 and delineated forest patches at a resolution of 1:10,000.

Patch Quality Index

I classified forest patches on the YDP to reflect observed habitat structure and patch size used by spruce grouse. One weakness of this approach is the inability to ground truth land cover in the historical aerial imagery. My interpretation of satellite images for 2011 was reinforced by on the ground observations during the larger habitat study. I used an ordinal ranking system to offer a robust measure of patch quality for spruce grouse and to minimize the effects of discrepancies that may have occurred when interpreting the historical images.

Vegetation composition and density are both important for spruce grouse, and it would be unwise to analyze the landscape without combining these factors. I classified forest patches by independently scoring both patch size, and structure perceived from aerial photography (Table 3.1). Deciduous stands, clear cut patches, buildings, open water, and open wetlands were given a forest structure score of "0" for "non-habitat". Coniferous stands interpreted as early or late successional stages, based upon canopy cover, were given a forest structure score of "1" for "intermediate habitat". Coniferous stands interpreted as mid-successional were given a forest structure score of "2" for "good habitat".

Results from the overarching study (Hill 2015) suggest spruce grouse on the Yellow Dog Plains rarely occupy patches less than 13-14 ha. This finding is consistent with Turcotte et al.'s (2000) estimates of spruce grouse home ranges averaging 13- 33 ha (in southern Quebec, Canada). I scored patches based on home range sizes reported in the literature (Turcotte et al. 2000). A patch less than 13 ha was given a size score of "0" for "non-habitat" (Table 3.1). A patch ranging from 13 to 33 ha was scored "1" for "intermediate habitat", and all other patches were scored "2" for "likely habitat".

Each forest patch was assigned a patch quality index based upon forest structure and patch size scores (Table 3.2). Any patch with a "0" score was ranked "non-habitat". Patches that scored 1 for both size and forest structure were ranked "poor habitat". Patches that scored 1 and 2 for either size or forest structure were ranked "fair habitat". Patches that score 2 for both size and forest structure were ranked "good habitat". Forest patches were classified by associated patch quality index and converted to raster format for analysis using FRAGSTATS (v4.2.1.603, McGarigal and Ene 2013).

Landscape Analysis

I analyzed the composition and spatial configuration of habitat on the YDP at the landscape, class, and patch level using FRAGSTATS software. Statistics were generated for the years 1937, 1967, 1978, 1987, and 2011.

I used Landscape Division Index (Jaeger 2000, McGarigal and Ene 2013) to measure the change in fragmentation on the Yellow Dog Plains. The Division Index is based on the distribution of cumulative patches. Results are reported as the probability that two randomly chosen pixels on the landscape do not belong in the same habitat patch. I also used Edge Density to compare edge length on a per unit area basis (McGarigal and Ene 2013). This statistic allows comparison among landscapes of varying size, and in this case, comparisons of the same landscape through time.

Class percent of the landscape was calculated to determine the proportional abundance of each class on the YDP. Percent of the landscape is a class-based metric used to describe the landscape and is useful for comparing changes in abundance of land cover as they might affect spruce grouse.

I used Euclidean Nearest-Neighbor Distance (Clark and Evans 1954, Mcgarigal and Ene 2013) to measure patch context on the YDP landscape. This simple, patch-based, metric represents the shortest edge-to-edge distance between habitat patches in the same class. I used this metric to describe patch context in the good habitat class and among all usable patches. I used the largest reported home range of spruce grouse in Southwestern Quebec, a landscape similar to the Yellow Dog Plains, to calculate a hypothetical search radius of 322 m. I used patch distances with the search radius to determine distances relevant to spruce grouse. To describe context among all usable patches I reclassified the landscape grouping classes 1, 2, and 3. The reclassified landscape resulted in two groups: usable habitat, and non-habitat.

RESULTS

The Yellow Dog Plains have become increasingly fragmented since the earliest available aerial image in 1937. Although the Landscape Division Index steadily increased, the Edge Density varied between 1937 and 2011 (Figure 3.3). This suggests varying changes in patch size and shape, rather than consistent directional change such as becoming increasingly smaller or more irregular. The greatest increase in Division Index was between 1987 and 2011 with a jump from 79% to 93%. The greatest increase in edge density happened at the same time, increasing from 15 to 30 m/ha.

Spruce grouse habitat was dynamic on the Yellow Dog Plains. Non-habitat occupied most of the landscape in 1937, but decreased to less than 10% in 1967 (Figure 3.4). Since then, amount of non-habitat has steadily increased while good habitat decreased proportionately. Proportion of fair habitat on the landscape has remained relatively unchanged since 1967. Poor habitat represents the smallest class on the landscape and was not detected in 1967 or 1987.

The distance to nearest usable patch fluctuated with no distinct trend (Figure 3.5). In 1967, combined habitat patches created one connected fragment resulting in a distance of 0 m. The distance metric to nearest good habitat patch does not consider patches classified as non-habitat, poor, and fair (Figure 3.6). Except for 1987, nearest distance to the next patch of good habitat were beyond the calculated search radius.

DISCUSSION

Rebertus and Danneman (2005) reported that the northwestern corner of the YDP was heavily cutover and burned by 1905. Large-scale clearing of forests by unregulated logging likely explains the large proportion of non-habitat classified in 1937 (Figure 3.7).

As a species dependent on disturbance, spruce grouse occupy mid-successional pine stands (Boag and Schroeder 1992). The disturbance caused by unregulated timber harvest and fire in the late 1800s and early 1900s resulted in an abundance of good habitat for spruce grouse in the latter half of the 1900s. This is most reflected in the single contiguous patch of usable habitat in 1967 (Figure 3.8).

After 1967, results show a steady decline in good spruce grouse habitat, and a slow increase of non-habitat and fair habitat (Figures 3.9-3.11). As a habitat specialist, spruce grouse are probably sensitive to habitat loss (Devictor et al. 2008). The spruce grouse is a sedentary species, but their home range varies depending on forest context. Year round home ranges may differ in different forest systems. For example, Ellison (1974) reported home ranges of 100 to 150 ha in the vast forests of Alaska.

The hypothesized search radius of 322 m represents a general, very conservative, distance an individual spruce grouse might use during a year. This metric is not intended to represent dispersing grouse whose movements may be much farther (Schroeder 1986). A comparison of search radius and average distance to nearest usable habitat patch suggests the landscape was relatively connected for grouse. However, when only good habitat patches were compared, they were more disjunct.

MANAGEMENT IMPLICATIONS

Although habitat loss and fragmentation are ever-present threats, conservation activities intended to benefit spruce grouse need to be conducted in ways that incorporate local resource needs to make lasting progress. In the Upper Peninsula of Michigan, for example, improving habitat connectivity needs to be done in a manner that fits within the context of timber harvest, which provides resources that support the local economy.

The future for spruce grouse in Michigan is uncertain because there is no large-scale effort to monitor their population or improve management practices. Because they are not migratory, or a game species in Michigan, they do not receive monitoring or research attention under the Pittman-Robertson Act or Migratory Bird Treaty Act. But if forests are harvested at scales relevant to spruce grouse, it may be possible to ensure adequate habitat while achieving timber harvest goals. These actions would likely help secure spruce grouse populations in the state, in the future

TABLES AND FIGURES

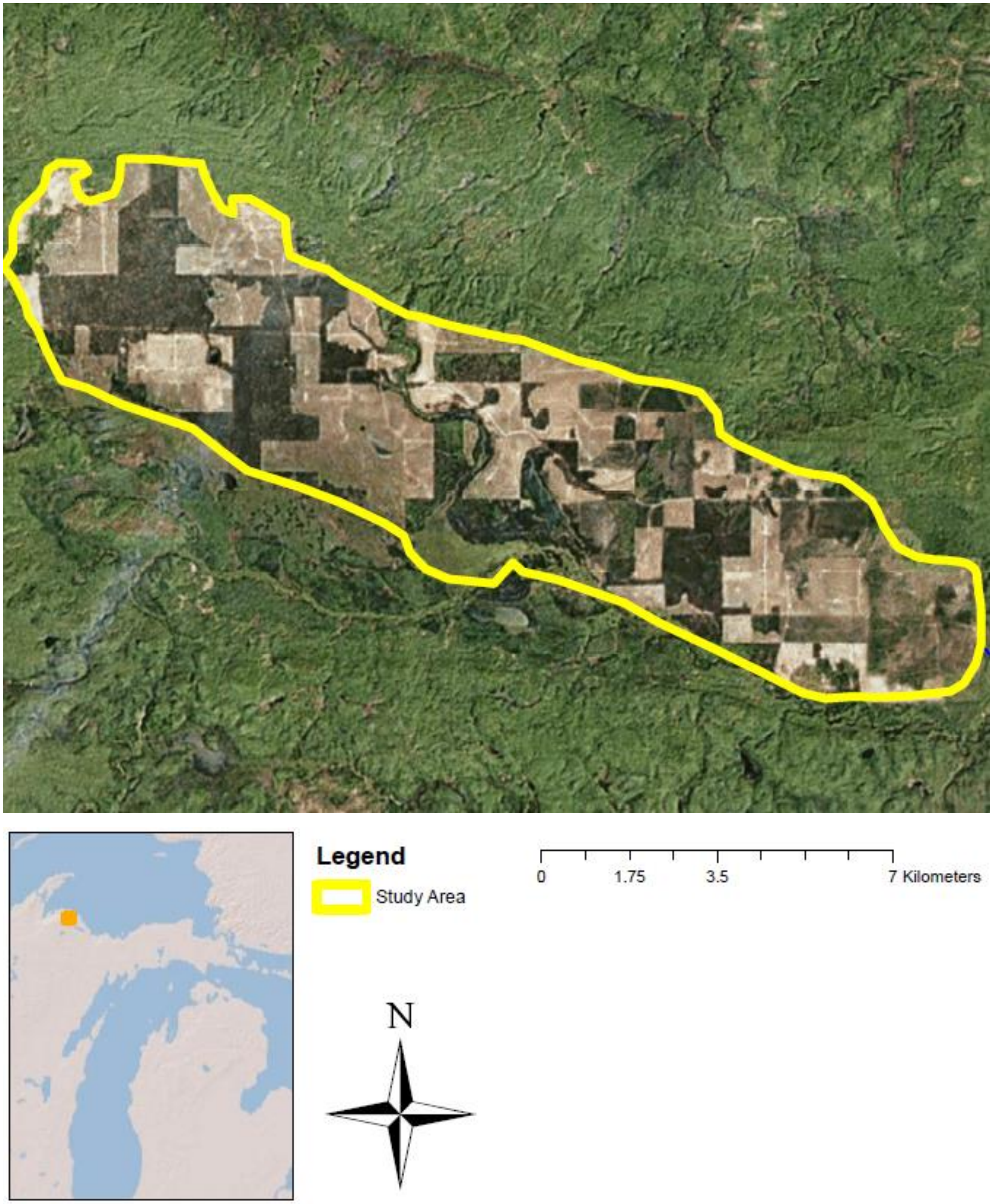


Figure 3.1: Yellow Dog Plains study area in Marquette County, Michigan.

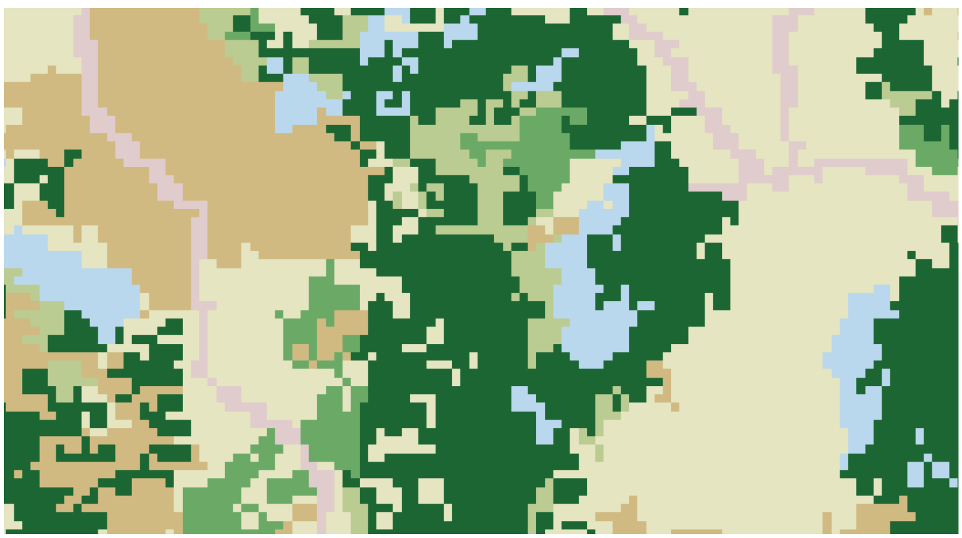


Figure 3.2: An example of the Yellow Dog Plains landscape (Fry et. al. 2011). Forest patches exist as part of a matrix of variable condition and quality for spruce grouse. Blue indicates woody wetlands, dark brown is shrub/scrub, and light brown represents grassland/herbaceous cover. Shades of green represent evergreen and mixed forests.

Table 3.1: Forest patches on the Yellow Dog Plains in Marquette County, Michigan 2013-2014 were classified based on habitat use reported in the literature for this region, (Robinson 1980, Anich et al. 2014a, Hill 2015 Chapter 2). Size scores were based on reported home range (Turcotte et al. 2000).

Patch Score Matrix

Patch Size Score		Habitat Quality Score	
0	Patches less than 13 ha	0	Patches composed of deciduous stands, clear cuts, buildings, open water and wetlands.
1	Patches between 13 and 33 ha	1	Patches composed of early or late successional forests.
2	Patches greater than 33 ha	2	Patches composed of mid-successional coniferous forests.

Table 3.2: Forest patches on the Yellow Dog Plains in Marquette County, Michigan 2013-2014 were ranked based on a combination of patch size and habitat quality scores. Low scores were assigned low index values and high scores were assigned high index values. Patch quality indices reflect respective habitat suitability for spruce grouse.

Patch Ranking Method		
Score	Suitability	Quality Index
0:0, 0:1, 0:2, 1:0, 2:0	Non-habitat	0
1:1	Poor habitat	1
1:2, 2:1	Fair habitat	2
2:2	Good habitat	3

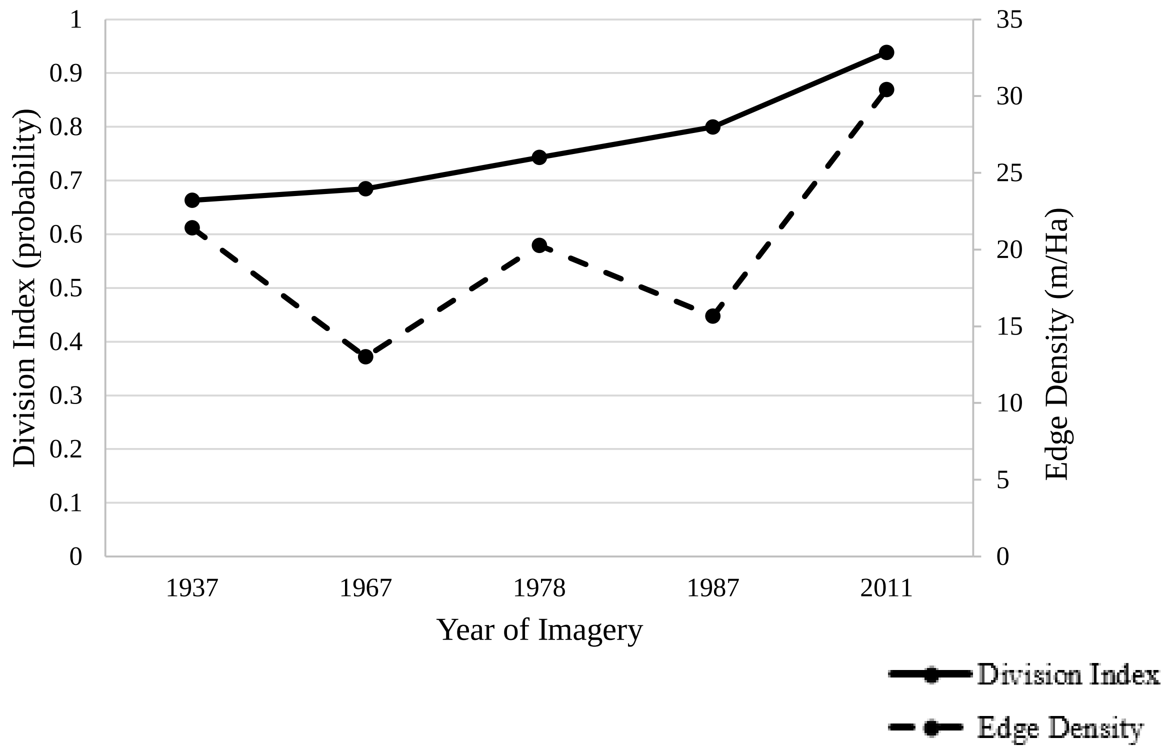


Figure 3.3: Fragmentation and edge density on the Yellow Dog Plains in Marquette County, Michigan from 1937 to 2011.

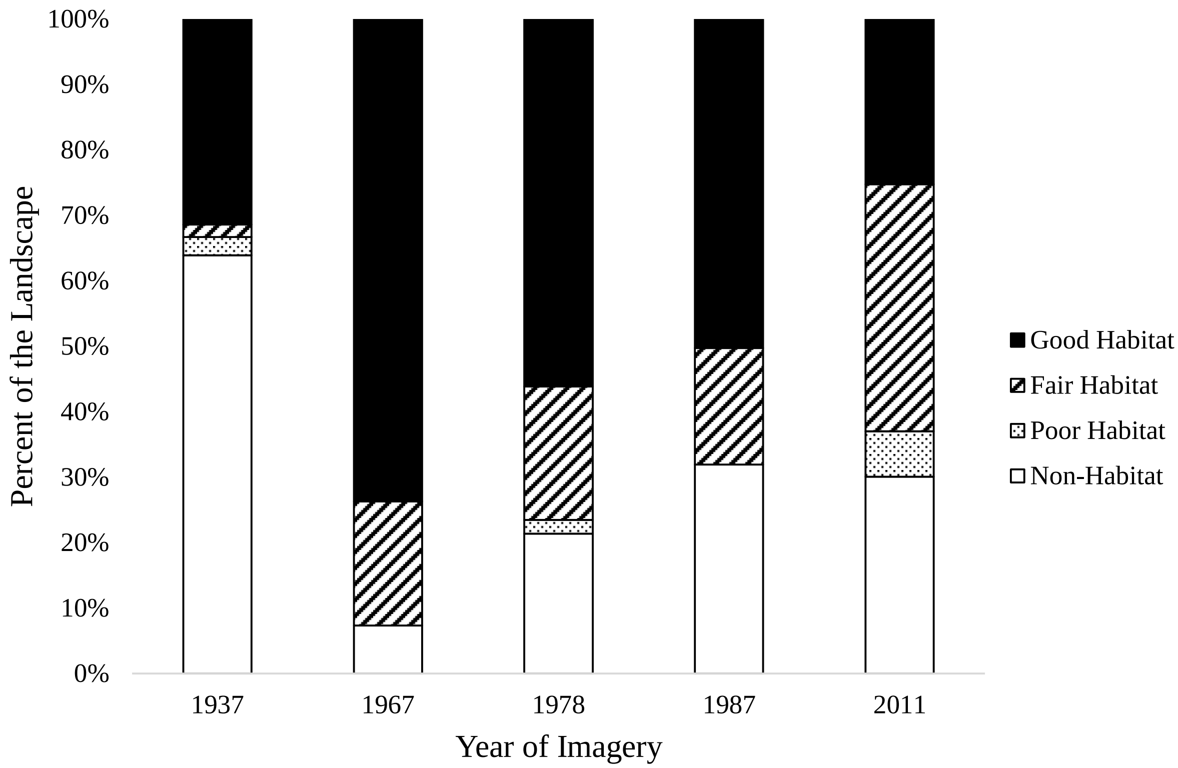


Figure 3.4: Proportion of spruce grouse habitat on the Yellow Dog Plains landscape in Marquette County, Michigan, 1937-2011.

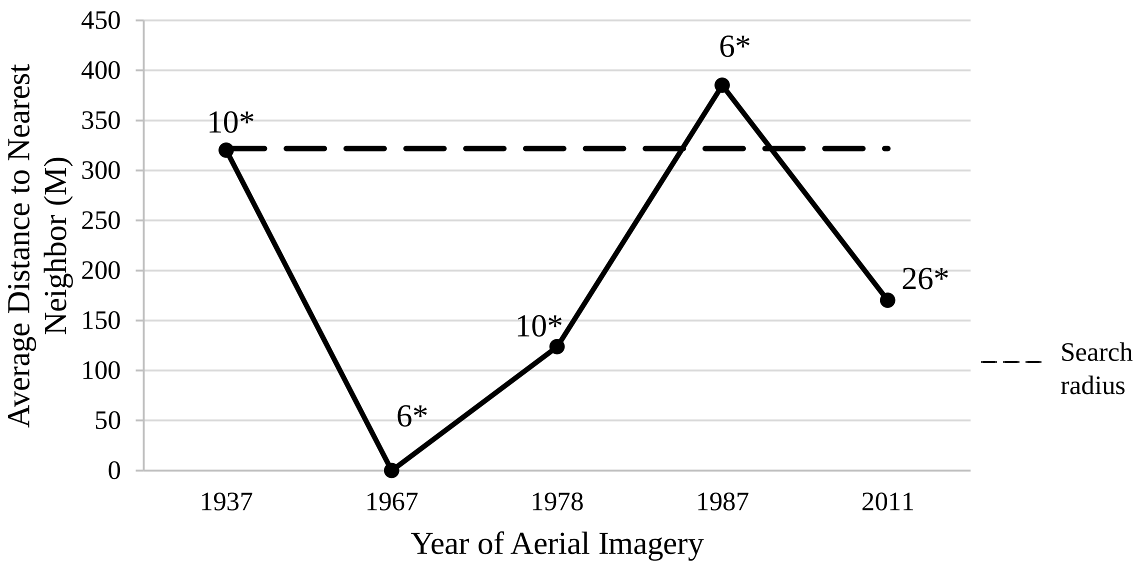


Figure 3.5: Distance to nearest patch occupiable by spruce grouse on the Yellow Dog Plains, Marquette County, Michigan, 1937-2011. Occupiable patches were defined as having a habitat quality index greater than “0”. Spruce grouse search radius was determined by smallest reported home range (*indicates number of patches).

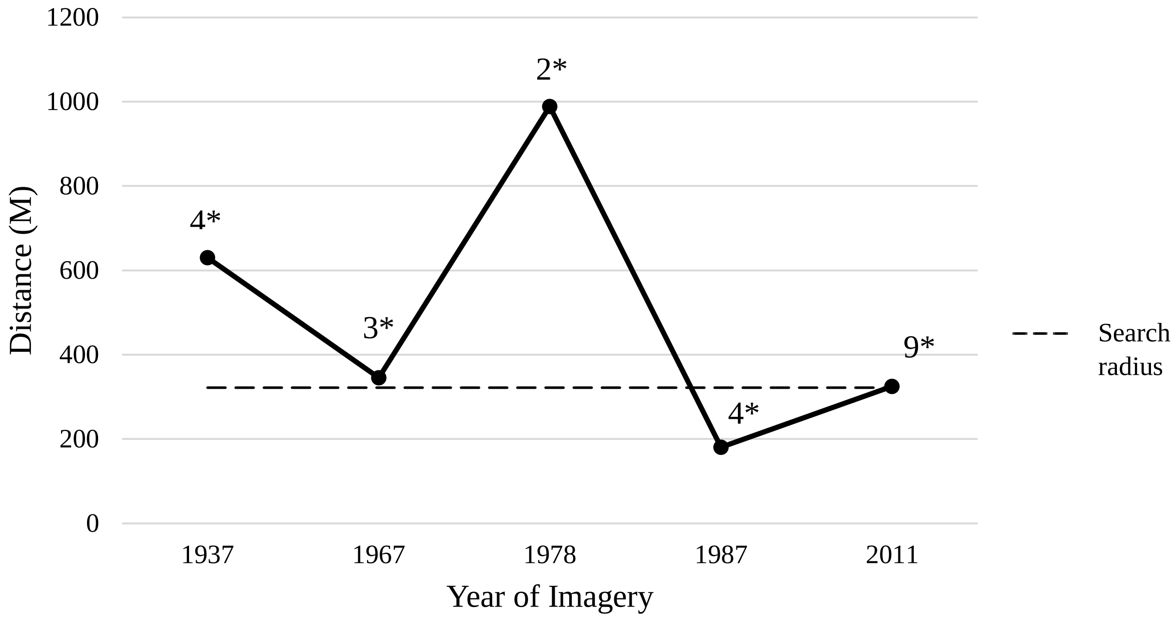


Figure 3.6: Distance to nearest patch good habitat for spruce grouse on the Yellow Dog Plains, Marquette County, Michigan, 1937-2011. Good habitat patches were defined as having a habitat quality index of “3”. Spruce grouse search radius was determined by smallest reported home range (*indicates number of patches).

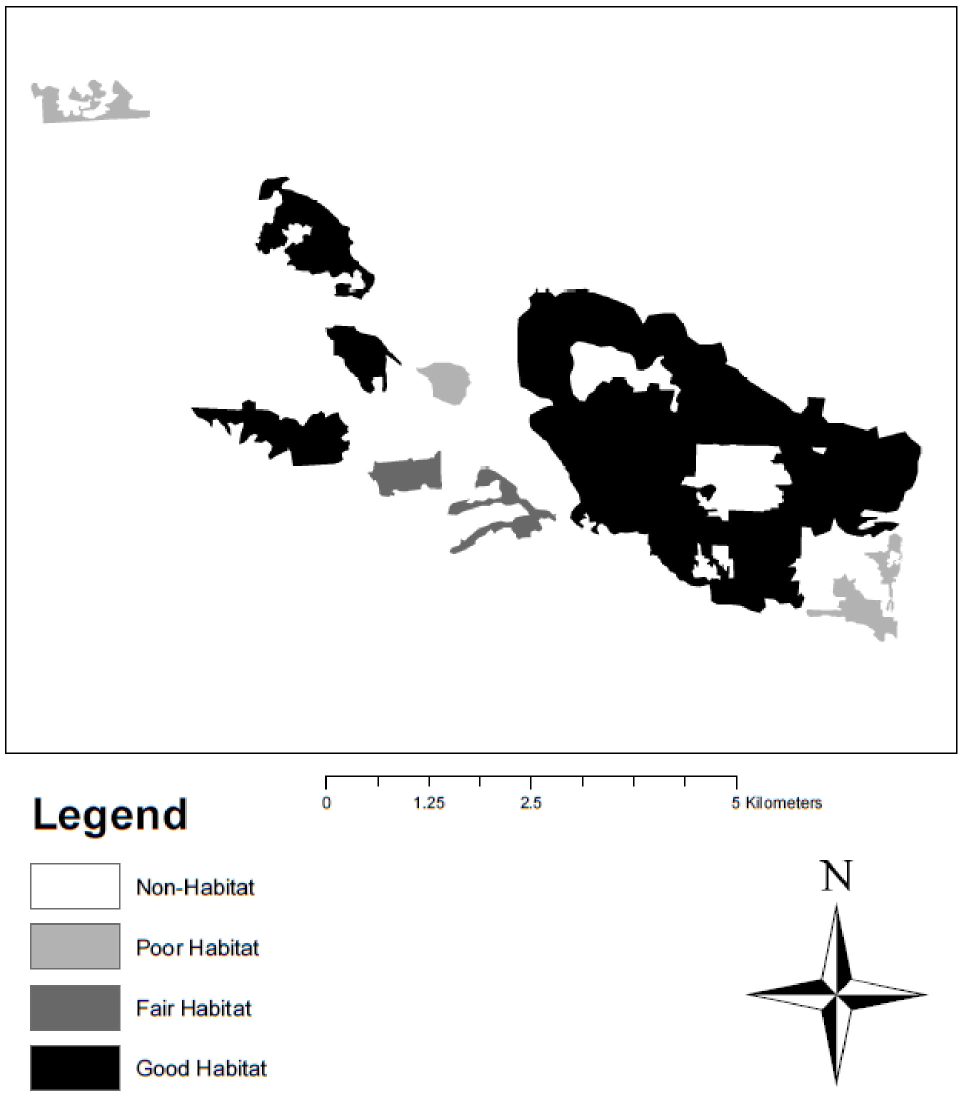


Figure 3.7: Distribution of spruce grouse habitat interpreted from 1937 aerial imagery, on the Yellow Dog Plains in Marquette County, Michigan.

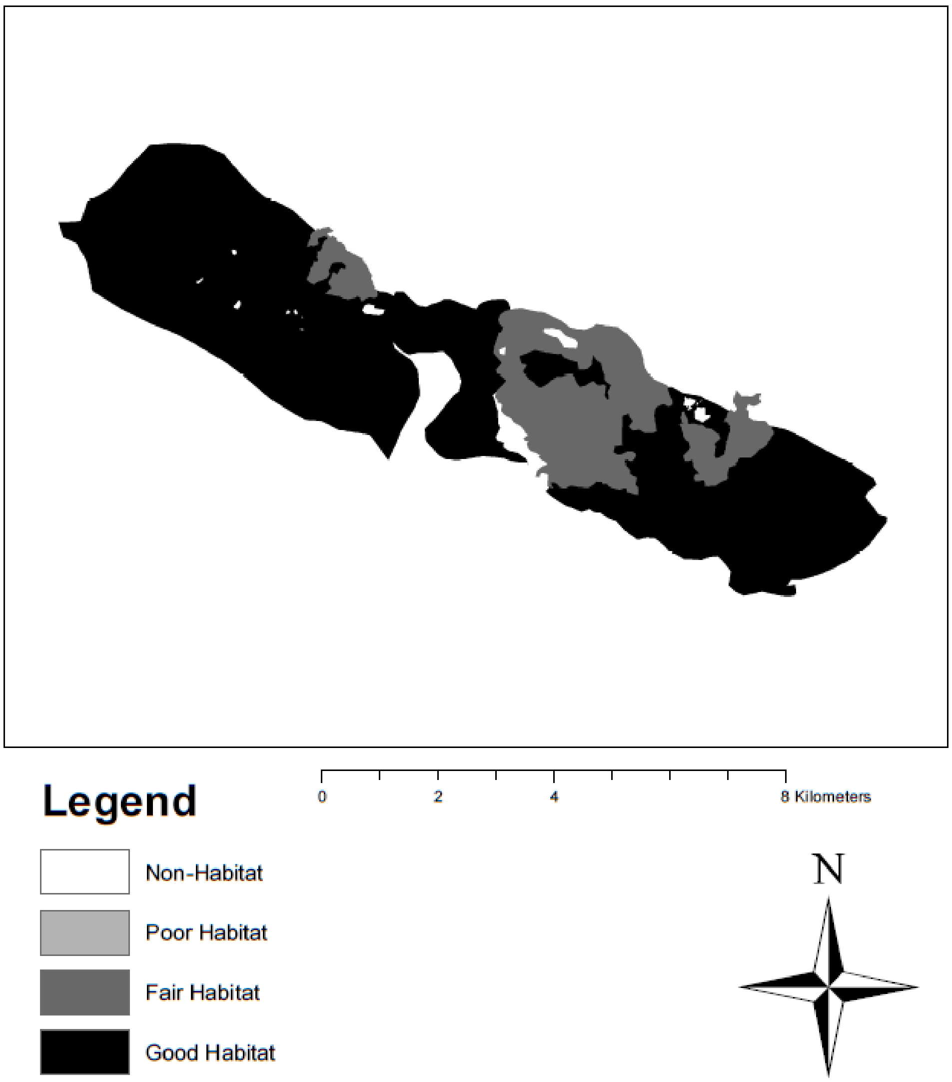


Figure 3.8: Distribution of spruce grouse habitat interpreted from 1967 aerial imagery, on the Yellow Dog Plains in Marquette County, Michigan.

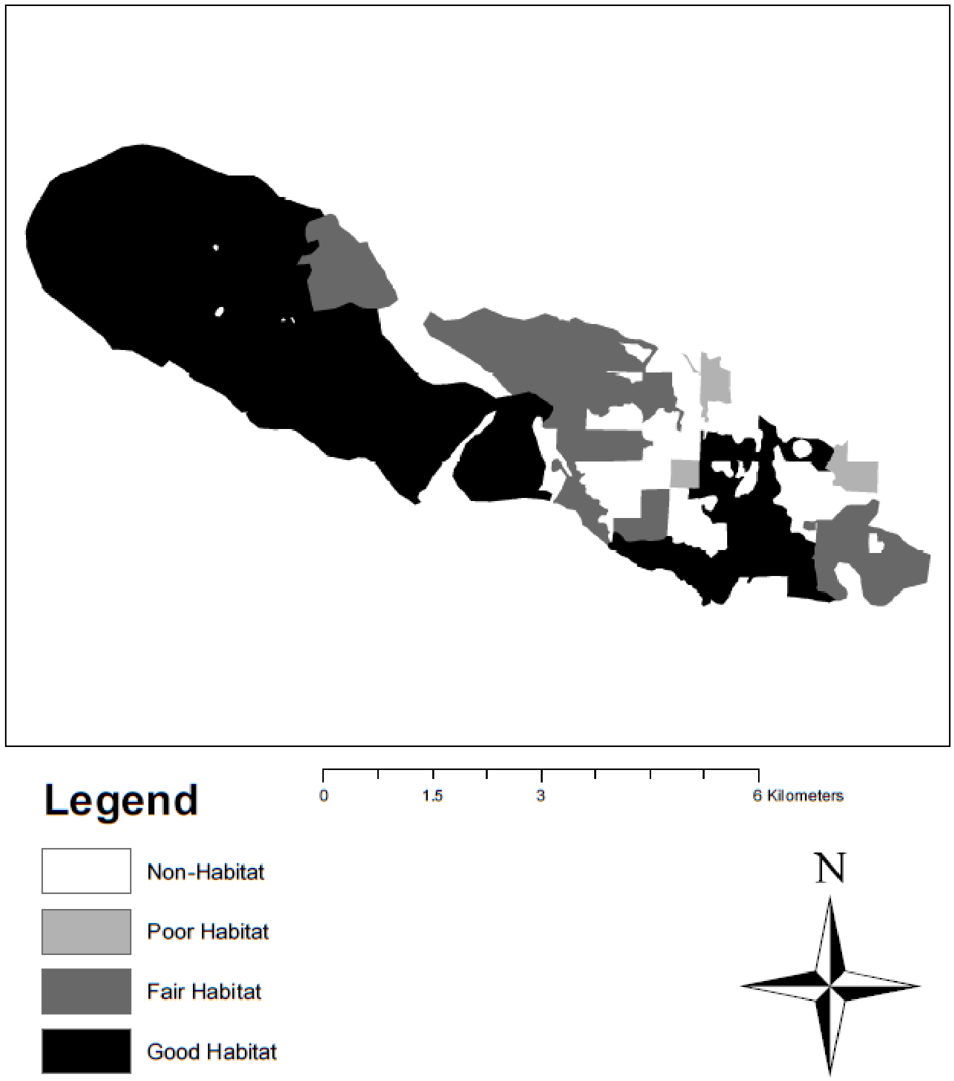


Figure 3.9: Distribution of spruce grouse habitat interpreted from 1978 aerial imagery, on the Yellow Dog Plains in Marquette County, Michigan.

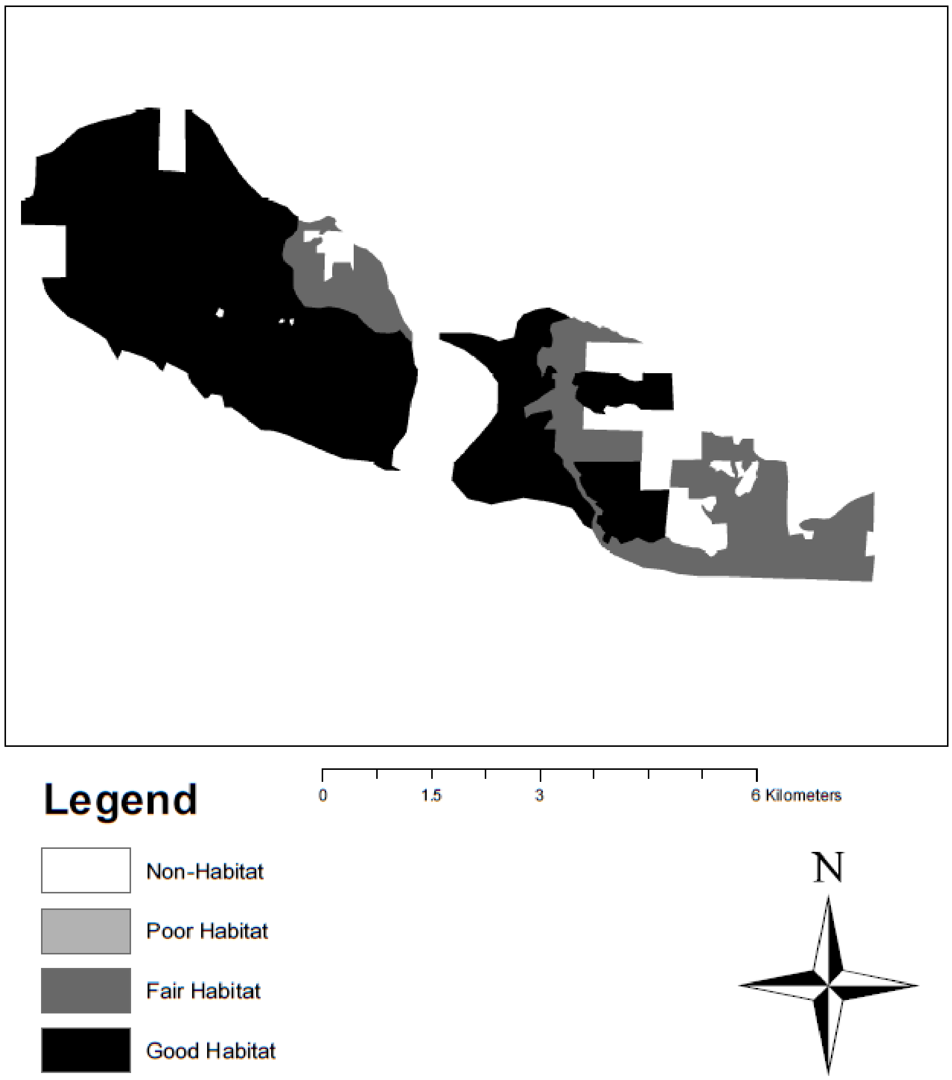


Figure 3.10: Distribution of spruce grouse habitat interpreted from 1987 aerial imagery, on the Yellow Dog Plains in Marquette County, Michigan.

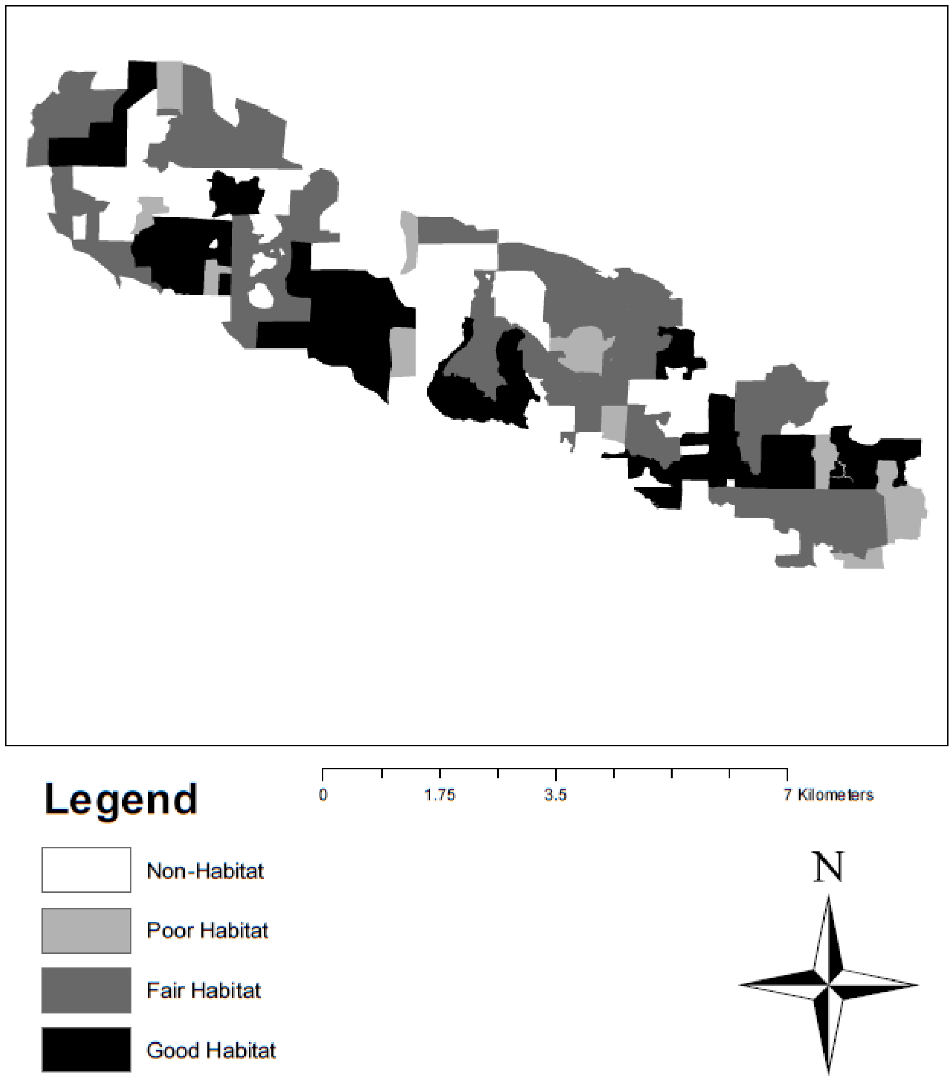


Figure 3.11: Distribution of spruce grouse habitat interpreted from 2011 aerial imagery, on the Yellow Dog Plains in Marquette County, Michigan.

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