PRODUCTIVITY AND HABITAT FEATURES OF SWAINSON'S HAWKS (*BUTEO SWAINSONI*) NESTING IN SUBURBAN AND AGRICULTURAL AREAS OF SOUTHWEST IDAHO

by

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The following individuals read and discussed the thesis submitted by student Steven Edward Alsup, and they evaluated his presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

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ABSTRACT

I compared nesting success and productivity of Swainson's Hawks nesting in suburban and agricultural areas in southwest Idaho to assess the effects of land use change on Swainson's Hawk reproduction. I also evaluated habitat parameters and land use patterns around nesting areas to determine if nest site, habitat, and/or landscape features were related to reproductive success in Swainson's Hawks. I recorded habitat characteristics, nest tree characteristics, distances to four habitat features, and disturbance types, as well as land use patterns within a 1500m radius around nest trees to assess any differences in nest site characteristics, habitat features, and/or landscape features between Swainson's Hawk territories in suburban and agricultural areas. During 2007 and 2008, I monitored nesting success and productivity of 74 breeding attempts. For both years combined, nesting success was higher in suburban areas (88.9%) than in agricultural areas (71.1%), and the difference approached significance. I found no significant difference in the number of young fledged per laying pair between the two areas; however, brood size at fledging was significantly higher in agricultural areas. Separate univariate logistic regression models for both nesting success and productivity showed negative associations with increased percent of uncultivated land within the nesting buffer, increased distance to water, and increased distance to dwelling. AICc model selection indicated that a model with the single predictor variable (distance to water) was the best predictor of nesting success. Distance to water was included in the top 14 models produced by the model selection process, and after evaluating other predictor

variables included in the top models, I found that including additional variables did not increase the predictive power.

My results indicate that Swainson's Hawks are able to reproduce successfully in suburban areas despite reductions in foraging areas due to human development. However, pairs nesting in suburban areas may suffer from reduced brood size at fledging, indicating that there are some reproductive constraints associated with nesting in suburban environments, such as increased energetic demands associated with increased distance to foraging areas, lower prey delivery rates, and the possibly of brood reduction.

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Introduction

Urbanization

Human activities can have many effects on native habitats including habitat destruction, degradation, and fragmentation. High levels of landscape alteration can lead to complete loss of native habitat, and increased extinction rates, and therefore cause a reduction in biodiversity (Chapin III et al. 2000). Of the numerous human activities that can cause habitat loss, urban development produces some of the greatest local extinction rates and can eliminate many of the native species in an area (McKinney 2002). Urbanization is the process of human settlement that gradually transfers wildlands uninhabited by humans into lands containing some degree of permanent human presence (Marzluff et al. 2001). Urbanization is continuous, and the range of human settlement patterns is often referred to as a gradient of urbanization (Marzluff et al. 2001). However, when describing the degree of development imposed on a particular area, the following categories (from least developed to most developed) are frequently used: wildlands, exurban or rural, suburban, and urban (Appendix A).

Rapid urbanization is occurring across much of the globe, including many areas of the United States (Cohen 2006). Loss of habitat, habitat degradation, and habitat fragmentation affect many plant and animal species (McDonald et al 2008). As patterns of land use change across a landscape, some species are able to adapt, but in many areas these changes occur too quickly for a species to respond. In many cases, species are forced to make tradeoffs in habitat quality. As a landscape undergoes land use changes, important foraging areas or areas for reproduction for a given species may be degraded. An area that previously provided high quality habitat may now only provide low or poor quality habitat. If land use patterns change too drastically or too quickly, a threshold may be reached. At a certain level of alteration, an area will no longer provide the habitat needed for a given species. Identifying environmental tradeoffs and finding threshold limits is important for maintaining biodiversity in an area. Yet, only recently have studies addressed how these changes affect individual species and entire ecosystems.

Effects of Urbanization on Raptor Species

Human development and activity can be either beneficial or detrimental to raptor populations. As human activities change natural environments, they affect several factors important to the survival of raptors, including food and nest site availability, habitat connectivity, vegetative structure, predation, competition, disturbance, climate, and pollution levels (Marzluff et al. 2001).

Sometimes, changes in these factors can be beneficial. For example, Mississippi Kites (*Ictinia mississippiensis*) adapt well to increased development, probably due to an increase in suitable nest trees and in insect prey around agricultural areas in the Great Plains and the Southwest (Parker 1996). Red-shouldered Hawks (*Buteo lineatus)* and Cooper's Hawks (*Accipiter cooperii*) have benefited from the introduction of non-native trees in suburban areas, and appear not to be negatively influenced by the level of human development around nest sites (Bloom and McCrary 1996, Rottenborn 2000, Mannan et al 2007). The Peregrine Falcon (*Falco peregrinus*) is probably the most well-known species to adapt to urban environments (Cade et al. 1996). The peregrine's ability to nest on man-made structures such as skyscrapers and suspension bridges, and its ability to adapt to urban prey populations has been an important factor to the species' establishment in urban settings (Tordoff and Redig1997). Merlins (*Falco columbarius*) have also adapted well to urban environments where their reproductive success has been found to be among the highest reported for their species (Sodhi 1992).

Although some raptors have responded positively to increasing urbanization, other species have shown negative responses. Ferruginous Hawks (*Buteo regalis*), for example, have decreased as grasslands have been cultivated (Schmutz 1987), and conversion of native prairie grasslands to agriculture has also contributed to declines in Northern Harrier (*Circus cyaneus*) populations (MacWhirter and Bildstein 1996). Large-scale agricultural practices have been detrimental to breeding Prairie Falcons (*Falco mexicanus*), primarily due to a reduction in biomass of prey in agricultural areas verses native rangelands (Steenhof 1998). Urbanization and human activity have also made many important breeding and wintering locations less suitable for Golden Eagles (*Aquila chrysaetos*) due to a reduction in black-tailed jackrabbit (*Lepus californicus*) populations (Kochert et al. 2002).

<u>Swainson's Hawk Natural History</u>

It is unclear at this point how Swainson's Hawks have responded to increasing human development. Historically, the Swainson's Hawk was found in grassland and shrublands across Midwestern and western North America from the northern Great Plains of Canada to semi-desert areas of northern Mexico. Recently, it has declined throughout much of its range including the Canadian prairies, Nevada, Oregon, and California (England et al. 1997). Several factors are thought to have contributed to this decline, including changes in agricultural practices, degradation and loss of nesting and foraging habitat, reduced prey numbers, and urban sprawl (England et al. 1997).

Swainson’s Hawks make one of the longest migrations of any raptor species (England et al 1997). Most of them leave their breeding grounds from mid-August to late October, and fly over 12,000 km to reach the pampas of South America (Fuller et. al.1998, Kochert et. al. 2011). During migration, Swainson’s Hawks can aggregate in groups of thousands while moving southward toward their austral summer grounds. In February and March, they begin their northward migration to breeding grounds across western North America.

The Swainson’s Hawk is a generalist species that readily adapts to anthropogenic disturbances, including many types of agricultural practices (Gilmer and Stewart 1984, Estep 1989, Bechard et al. 1990, James 1992). Breeding Swainson’s Hawks feed primarily on vertebrates such as small mammals, birds, and reptiles. Non-breeding Swainson’s Hawks have been found to rely heavily on insect prey (England et al. 1997). Vegetation height and density are important factors related to prey availability and foraging by Swainson’s Hawks (Bechard 1982). Alfalfa provides optimal foraging areas for Swainson’s Hawks because of the harvesting practices associated with this crop. Early in the growing season and shortly after harvest, alfalfa fields provide low prey concealment and high prey density. Male Swainson’s Hawks in northern California have been found to select alfalfa fields and grass more than expected based on availability and

93% of use occurred during harvesting activities and before plant heights reached 9 cm (Woodbridge 1991). Estep (1989) found that alfalfa fields supported only moderate prey densities, but monthly mowing and weekly flood irrigation lead to high prey availability.

Currently, many cities and towns across the Swainson's Hawk's range are experiencing a boom in urban growth (Auch et al. 2004). Areas that were once sparsely settled and dominated by small farms are being converted to industrial and residential areas. The reduction of agricultural areas associated with changes in land use patterns may have negative effects on Swainson's Hawk reproductive performance.

Effects of Urbanization on Swainson's Hawks

While Swainson's Hawks appear to benefit from certain types of agricultural practices, the level of suburban/urban development that it can tolerate is poorly understood. About 75% of 270 Swainson's Hawk nesting areas in North Dakota were attributed to planting of trees by humans, and nesting success within 500 m of farmhouses was similar to nests greater than 500m from farms (Gilmer and Stewart 1984). Of 61 nest trees in the central valley of California, 35% were within 0.4 km of farmhouses or residential areas and 32% were within 0.4 km of busy county roads or highways; nesting success or productivity did not differ between nest sites close to human activities and those away from human activity (Estep 1989). In Washington, Swainson's Hawks nested closer to roads and human structures than did Red-tailed Hawks (*Buteo jamaicensis*) or Ferruginous Hawks, with 42% of their nests occurring within 1.0 km of buildings (Bechard et al. 1990). Conversely, Swainson's Hawks were more abundant in areas of moderate cultivation than in grasslands or in areas of extensive cultivation (Schmutz 1987), suggesting that a double threshold may exist related to the level of human development imposed upon a landscape. At the upper end of this threshold, Swainson's Hawks may be constrained by high levels of human development, and at the lower end of the threshold, they may be constrained by too little agricultural land use in an area.

Recently, studies have shown that many Swainson's Hawks nest in areas with increased human development and activity (i.e., suburban areas). High density of suitable nest trees, availability of a main prey species, and less human persecution within Regina, Saskatchewan, Canada was considered to have attributed to Swainson's Hawks nesting in this suburban area (James 1992). However, nesting in suburban areas has associated costs. Hawks nesting in suburban areas must sometimes travel long distances to forage, thus increasing their energetic demands (Estep 1989, Babcock 1995). This increased energetic demand can result in decreased reproductive success (England et al. 1997). Swainson's Hawks nesting in suburban areas in and around Davis and Stockton, California had lower productivity and nesting success than those nesting in adjacent agricultural areas, and were among the lowest values reported for the species (England et al. 1995). Swainson's Hawks were absent from urban centers that did not contain suitable foraging habitat within 5-8 km of nest trees. The age of the neighborhood also affected use by Swainson's Hawks; hawks nested in neighborhoods >20 years old more frequently than expected and preferred neighborhoods >45 years old, due to mature landscaping. England et al. (1995) cautioned that rapid urbanization and changes in crop types could negatively affect Swainson's Hawk populations. Although Swainson's Hawks foraged up to 15 km from their nests, these long distance flights usually occurred when food availability closer to nests was temporarily reduced (Estep 1989, Babcock 1995). Prey captured far from nests was usually consumed immediately, and prey items used to provision young or a mate were usually captured close to nests (Babcock 1995).

Swainson's Hawks in Southwest Idaho

Many Swainson's Hawk nesting territories occur within increasing suburban areas near Boise, Idaho, and by 2005 many had been surrounded by housing developments (USGS Unpubl. data). There is concern that as agricultural areas are rapidly developed into industrial, commercial, and residential areas, Swainson's Hawks will be forced to forage farther from their nests, and energetic constraints imposed on them could increase. This increase could result in a reduction in nesting success and/or productivity in these developed areas, and lead to an overall decline of the species in this region.

Preliminary results from a long-term study of Swainson's Hawks breeding in southwest Idaho were inconclusive in terms of the relationship between Swainson's Hawk reproduction and suburbanization. No clear pattern in productivity and nesting success was observed between Swainson's Hawks nesting in primarily rural/agricultural areas, and those nesting in predominantly suburban areas (USGS Unpubl data). This comparison was hindered by low sample size, which did not allow for robust statistical comparisons.

Objectives

My objectives were to:

1) Determine the effects of suburban development on Swainson's Hawks by increasing the sample size in suburban areas to allow for more rigorous statistical comparisons between agricultural and suburban areas.

2) Assess any differences in nest site, habitat, and landscape features between suburban and exurban/rural areas to determine if any difference existed between the two areas.
3) Determine if a decrease in high quality foraging habitat (i.e., alfalfa fields) or an increase in developed area (i.e., suburban housing, commercial or industrial areas) reduced nesting success and/or productivity in Swainson's Hawks.

I predicted that nesting success and productivity would be higher in agricultural environments than in suburban environments. I also predicted that higher nesting success and productivity would be related to an increased amount of foraging area within nesting areas or decreased distances from nests to potential foraging areas.

Methods

<u>Study Areas</u>

The study areas were within Ada county and the eastern edge of Canyon county in the Treasure Valley of southwestern Idaho. The Boise-Meridian study area was the northernmost area, and included the cities of Boise and Meridian. The Kuna-Melba area included the towns of Kuna and Melba, and was the southernmost area (Figure 1). The Boise-Meridian area was bordered to the north by the Boise River and to the south by the Kuna-Melba area. The Kuna-Melba area was bordered by the Boise-Meridian area to the north and by the Morley Nelson Snake River Birds of Prey National Conservation Area to the south. The eastern border of both study areas was Pleasant Valley Road and the western border was Highway 45. The study areas were representative of an suburbanization gradient seen in many growing cities and towns.

The Kuna-Melba area was the least developed and was mostly rural, although the population of the small town of Kuna increased significantly between 2000 and 2008 (Appendix B). Kuna was surrounded mostly by agricultural fields, but the area also included pasture land, feedlots, dairies, as well as some uncultivated areas. The Boise-Meridian area was the most developed. Except for the urban center of downtown Boise, the area was mostly suburban. Rapid development occurred starting in the early 1900s, and many farms were being converted into residential, commercial, and industrial areas during my study (Appendix B). Several small patches of agricultural fields remained intact within the center of the area; however, conversion of agricultural fields to residential areas occurred rapidly along the edges of the Boise-Meridian study area.

Nesting Success and Productivity

I monitored breeding Swainson's Hawks from mid-April to mid-August, 2007 and 2008. I began searches for occupied territories after Swainson's Hawks returned from their wintering grounds and before trees leafed out and obscured nests. I observed nests and adults from a vehicle using 10X binoculars and a 20 - 60X spotting scope. I made observations from outside of a vehicle only when access with a vehicle was not possible. These observations were necessary at only five breeding areas. Initially, I searched historical nesting territories identified in a long-term study by the USGS Snake River Field Station. I began my search at nest trees used in 2006 and then searched other suitable nest trees within 500m of these nest trees. I also expanded my search effort within the Boise-Meridian study area to locate additional breeding areas. I identified several additional nesting areas in this area by observing perched or soaring Swainson's Hawks and then following them back to their nest trees.

A nesting territory was the confined area where a nest was found and where no more than one pair was known to have bred at one time (Steenhof and Newton 2007). A nesting territory was considered occupied if a pair of birds was present and courtship or nest building activities were observed, or if a bird was observed in a nest (Steenhof and Newton 2007). I considered a pair to have laid eggs if a hawk was observed in incubation position on a nest, or young were observed in a nest.

I visited nesting territories throughout the breeding season to monitor breeding attempts. The frequency of visits depended on the stage of the nesting season. Most nests were visited at least once per week. I monitored nests more frequently during nest building and egg laying periods to confirm that nesting pairs used specific nests and to locate nests before nest trees leafed out. I also visited nests more frequently when young were near fledging age, to obtain accurate brood sizes at fledging. I considered a nesting attempt successful if at least one nestling survived to 80% (31 days) of fledging age (Steenhof and Newton 2007). I monitored nests until they either failed or nestlings reached ≥31 days of age. I defined productivity as the mean number of nestlings that reached ≥31 days of age per nesting attempt (i.e., young per nesting attempt) and per successful nest (i.e., brood size at fledging).

Habitat and Landscape Features

I recorded nest tree features after fledging to reduce disturbance to nesting hawks. Features recorded included tree species, diameter at breast height (DBH), nest tree height, nest height, and position of the nest in the tree (main trunk, diagonal branch, horizontal branch). I classified nest trees into one of the following categories: single tree, tree in a linear stand, or tree within a non-linear group. I measured DBH to the nearest 0.1 meter using a DBH tape. I measured nest tree height and nest height to the nearest 0.1 meter using a clinometer and a digital range finder. Heights were calculated by measuring the angle to the top of the tree or to the nest and dividing by 100. This value was then multiplied by the distance from the nest tree that the angle was measured.

I assessed landscape features around nests using geographic information system (GIS) techniques and ground-truthing of maps. I used ESRI ArcGIS 9.3 software for all GIS analyses, and used a 2006 National Agriculture Imagery Program (NAIP) aerial image of Ada County as a base layer in the GIS. None of the nesting areas used in the analysis fell within the Canyon county portion of the study areas. I plotted nest locations over the NAIP image and created a circular buffer with a radius of 1500m around each nest tree. A nesting area was defined as the area encompassed by this circular buffer. Previous studies assessing habitat characteristics of breeding Swainson's Hawks have measured characteristics within radii ranging from 500m to 2000m (Gilmer and Stewart 1984, England et al. 1995, Bosakowski et al. 1996). I chose a radius of 1500m so that my results would be comparable to these previous studies. In addition, the area within the 1500m radius (706.8 ha) is within range of the home range values of nesting Swainson's Hawks calculated in other studies (Bechard 1982). However, reported values of home range size vary widely across studies (Estep 1989, Woodbridge 1991, Babcock 1995). I printed paper maps of each nesting territory (including nest site and circular buffer) and drove through each breeding area to assign land cover categories to the appropriate polygons. Land cover types included: developed areas (e.g., buildings, roads, parking areas), alfalfa/hay fields, grain crops, corn, fallow fields and pastures, other crops, uncultivated areas, and recreational areas (e.g., parks, golf courses, athletic fields). I used these maps to create land cover layers in the GIS. I created a shapefile for each land cover type, and using the editing mode in ArcMap 9.3, I created polygons within each nesting area that corresponded to each land cover type present within the circular buffer around each nest site. I calculated the area of all land cover types within each breeding area and calculated the percent of each land use category within a nesting area. I also calculated the distance from the nest tree to several other landscape features. These features included: distance to alfalfa fields, distance to road, distance to water feature, and distance to the nearest residential dwelling or other human made structure.

Analysis

I used SAS 9.1 statistical software program for all statistical tests (SAS Institute Inc., Cary, North Carolina), using an α-level of 0.05 for all tests. I used the GLIMMIX (General Linear Model for Mixture Distributions) procedure to test year as a random effect on logistic regression analyses. I found no effect of year; so I was able to analyze the data by combining both study years. Because some breeding Swainson's Hawks used the same nest in both breeding seasons and others used different nest trees, I produced Generalized Estimation Equations (GEE) using the GENMOD procedure to determine if repeated measures affected my results (Long 1997). Results were nearly identical regardless of whether data were analyzed with or without the repeated measure factor. Therefore, I analyzed the data without controlling for repeated measures.

I conducted two sample t-tests to assess differences in nesting success, productivity, and predictor variables between the two study areas. Further analyses were conducted by pooling nesting attempts from both study areas. To assess nesting success, I first ran a univariate logistic regression model, using the LOGISTIC procedure, to determine how individual predictor variables were related to nesting success. I used a binominal distribution to assess nesting success because there were two possible outcomes (successful or failed) for nesting success. I also ran a univariate logistic regression model to assess productivity (number of fledglings per nesting attempt); however, I used an ordinal distribution rather than a binomial distribution. For this analysis, I used 0, 1, 2, or 3 or more fledged as possible outcomes since only one nesting attempt out of 74 produced 4 fledglings.

I performed an Akaike's Information Criterion (AIC) model selection analysis to identify which variables or combination of variables influenced nesting success the most. This procedure gave a measure of the goodness of fit for an estimated statistical model, and also attempted to find the model that best explained the data while including the lowest number of parameters (Akaike 1974). I used a Corrected AIC (AICc) model selection process, which is a more appropriate procedure for model strength comparison on datasets with low sample size (Burnham and Anderson 2002).

To reduce the total number of variables used in the AICc process, I conducted a pairwise correlation analysis to identify highly correlated variables. I chose to eliminate one of a pair of variables if they had a correlation value >0.8. To determine which of the two correlated variables to eliminate, I ran the AICc process with one of a pair of correlated variables independently. I then eliminated the variable that produced the higher AICc value.

Results

Swainson's Hawk Reproduction

In 2007, I identified 20 and 41 breeding attempts, by Swainson's Hawks in the Boise-Meridian and the Kuna-Melba study areas, respectively. I included all nesting attempts in the Boise-Meridian area in the analysis and randomly selected 20 breeding attempts in the Kuna-Melba area to maintain equal sample sizes between the two study areas. One pair in the Kuna-Melba study area failed early, and subsequently re-nested, bringing the total breeding attempts to 21 in that study area.

In 2008, I observed breeding attempts in only 15 of the nesting areas occupied in the Boise-Meridian study area in 2007. I also located a breeding attempt in a historical territory that did not have a breeding attempt in 2007, bringing the total breeding attempts studied in the Boise-Meridian study area to 16 in 2008. I studied the same breeding areas in 2008 that I randomly selected in 2007 in the Kuna-Melba study area. However, I observed no breeding attempts in three nesting areas, reducing the total breeding attempts to 17 in the Kuna-Melba study area in 2008.

In the Boise-Meridian study area, 95.0% and 81.3% of laying pairs fledged young in 2007 and 2008, respectively (Table 1). Pairs produced an average of 1.70 young per nesting attempt in 2007 and 1.94 young per nesting attempt in 2008. Brood size at fledging increased from 1.79 young in 2007 to 2.38 young in 2008. In the Kuna-Melba study area, 61.9% and 82.4% of the laying pairs fledged young in 2007 and 2008, respectively. Pairs produced an average of 1.48 young per nesting attempt in 2007 and 2.12 in 2008. Brood size at fledging increased from 2.38 young in 2007 to 2.57 young in 2008.

For both years combined, 88.9% of nesting attempts were successful in the Boise-Meridian study area compared to 71.1% in the Kuna-Melba study area, and this difference approached significance (*t* = -1.95, *P* = 0.056, df = 66.1). I found no significant difference in the number of young fledged per nesting attempt in the Boise-Meridian study area (1.81 young) and the Kuna- Melba study area (1.76 young); (*t* = 0.16, *P* = 0.874, df = 72). However, brood size at fledging was significantly higher in the Kuna-Melba (2.48 young) than in Boise-Meridian (2.03 young); (*t* = -2.31, *P* = 0.025, df = 57); (Table 1).

<u>Habitat and Landscape Features</u>

All of the eight land use categories measured around Swainson's Hawks nests, except for percent of pasture and fallow fields, differed significantly between the study areas (Table 2, Figure 2). Nesting areas within the Boise-Meridian study area were dominated by developed areas (72.6%) (Figure 2, Figure 3), followed by pasture and fallow fields (15.4%), alfalfa fields (4.2%), and corn fields (2.4%) (Table 2, Figure 2). Nesting areas within the Kuna-Melba study area were dominated by agricultural fields (Figure 4), and overall had a more balanced mix of land use types (Table 2, Figure 2). They were comprised mainly of alfalfa fields (25.2%), uncultivated area (19.6%), corn fields (19.3), and pasture and fallow fields (13.2%) (Table 2, Figure 2). The amount of developed area within the Kuna-Melba nesting areas averaged (11.9%) (Table 2, Figure 2). Distances to alfalfa, dwellings, and water differed between study areas, and the range of these values was quite large (Table 3).

Cottonwoods (*Populus spp.*), black locusts (*Robina pseudoacacia*), and elms (*Ulmas spp.*) were the three most used species of nest trees (Table 4). There were no significant differences between study areas in relation to the nest position within nest trees (main branch, diagonal branch, horizontal branch), or with tree locations (single tree, tree in a linear stand, or tree within a non-linear group) (Appendix C).

Factors Related to Swainson's Hawk Nesting Success and Productivity

Nesting Success:

The univariate logistic regression model showed significant negative associations between nesting success and increased percent of uncultivated land within the nesting buffer, increased distance to water, and increased distance to dwellings (Table 5). The model also showed significant positive associations with greater nest tree height and increased percent of pasture/fallow fields within the nesting buffer (Table 5).

Tree height and nest height were highly correlated ($r = 0.894$, $P = <0.0001$, $n = 71$), as were percentage of uncultivated land within a nesting buffer and the distance to water from a nest ($r= 0.911$, $P = <0.0001$). I eliminated nest height and percentage of uncultivated land from the model selection process because these variables produced higher AICc values than the variable with which they were correlated. I also eliminated variables from the AICc process that had the highest p values in the univariate logistic regression, except for percent of alfalfa fields within the nesting buffer because it was a variable that I specifically wanted to evaluate in this study. After eliminating predictor variables based on correlations and univariate results, I entered 11 predictor variables into an AICc model selection procedure. Final predictor variables included: distance to water, distance to dwelling, tree height, percentage of pasture/fallow fields within the nesting buffer, distance to road, percentage of developed area within the nesting area, the percentage of grain crops within the nesting buffer, percentage of other crop types (excluding alfalfa, corn, or grain crops) within the nesting buffer, distance to alfalfa fields, and percentage of alfalfa fields within the nesting buffer.

Fourteen models were within 2 AICc units of the null model, and therefore were better predictors of nesting success than the null model. Because several models fell within 2 AICc units of the null model, I evaluated the top five models with the lowest AICc values for selection as the final model (Table 6). The lowest scoring AICc model ($\Delta i = 0$) included distance to alfalfa and distance to water. Distance to water was included in all of the top 14 models, and was the only variable in the second model.

Because distance to water was included in all the top models, and was the only variable in the second model, I assessed if inclusion of other predictor variables increased the predictive power of this single variable model. First, I examined the dataset for outliers and determined if any outliers had undue influence on the model and its fit. I found that no single nesting attempt (or group of nesting attempts) changed any model coefficients when removed from the final dataset. Therefore, I could conclude that no individual nesting attempt had undue influence on the overall fit of the model. I then fit each of the variables included in the top five models (distance to alfalfa, tree height, percent of alfalfa within the nesting buffer, and percent of pasture/fallow fields within the nesting buffer) with the distance to water variable and looked at the residual plots to find outliers and/or residual patterns. The plots looked similar regardless of the variable considered for addition into the model. I looked at leverage plots to determine an additional variable’s effect on the overall model, and DFBeta plots to determine the effect on an individual coefficient.

Finally, I added variables into the models and looked for large changes in coefficients. As new variables were added, the coefficients for distance to water did not change, or changed very little. In addition, when additional variables were included in the model, they were highly non-significant.

AIC values were similar for all five of the best fitting models (all of which had distance to water included), and distance to water alone had the second lowest AICc value. Based on this evidence, including additional predictor variables in the model did not increase the predictive power. Therefore, the simplest model (distance to water alone) predicted nesting success as well as any of the top models, and was chosen as the final model.

Productivity:

The univariate logistic regression model revealed significant negative associations between productivity (fledglings per nesting attempt) and increased percent of uncultivated land within the nesting buffer, increased distance to water and increased distance to dwelling (Table 7). A significant positive association occurred between productivity (fledglings per nesting attempt) and percent of pasture/fallow fields within the nesting buffer.

Discussion

Nesting Success and Productivity

Swainson's Hawk nesting success in my study tended to be higher in suburban than in agricultural areas, and the number of young fledged per nesting attempt was significantly higher in the suburban study area. However, an alternate measure of productivity, the number of young fledged per successful nest (also referred to as brood size at fledging) was significantly lower in the suburban study area. Thus, it appears that nests in suburban areas were more likely to be successful, but were also more likely to produce fewer young.

Other studies have shown conflicting results concerning nesting success and productivity. For example, Swainson's Hawks in a study by England et al. (1995) and Burrowing Owls (*Athene cunicularia*) in a study by Conway et al. (2006) had lower nesting success and fewer fledglings per nesting attempt in a suburban study area, but showed no difference in the number of young fledged per successful nest between suburban and rural study areas. However, Eastern Screech-Owls (*Otus asio*) had higher nesting success and more fledglings per nesting attempt in a suburban study area, and also showed no difference in the number of young fledged per successful nest between suburban and rural study areas (Gehlbach 1988). The number of Burrowing Owls fledged per successful nest decreased as developed area exceeded 60% within a study area in Florida (Millsap and Bear 2000). In contrast, the number of Cooper's Hawks fledged per successful nest in the city of Milwaukee, Wisconsin was one of the highest values reported for that species (Stout et. al 2007). Differences in reproductive performance exhibited by raptor species nesting in suburban environments may depend on differences in the nesting substrate a species uses, the type of prey they rely on, the type of foraging habitat they utilize, the species that prey upon them, and the level of human disturbance that they can tolerate.

Values for nesting success in my rural study area were within the range of values reported in previous studies, while nesting success in my suburban study area was the highest reported for Swainson's Hawks across their breeding range (Table 8). My values for the number of young fledged per laying pair and brood size at fledging in both study areas were also among the highest reported for the species. These data suggest that my study areas provided high quality habitat for breeding Swainson's Hawks. While I did not collect data on nesting density or nearest neighbor distances, I was able to locate about twice as many nesting areas in the Kuna-Melba study area. This suggested that the Kuna-Melba study area provided higher quality habitat than the Boise-Meridian study area.

Furthermore, the difference in brood size at fledging between my two study areas suggested that suburban nesting Swainson's Hawks may have been reproductively constrained in some way. Bechard (1983) showed that brood reduction can result from a lack of food in nesting Swainson's Hawks. If Swainson's Hawks nesting in suburban areas had lower prey delivery rates than hawks nesting in adjacent agricultural areas, brood reduction could explain smaller brood sizes associated with the Boise-Meridian study area. If one considers the two study areas as a whole, it seems as though Swainson's Hawks were limited to the north by urban/suburban development and to the south by the lack of cultivated area. This limitation supports the concept that this species faces two limiting factors in southwest Idaho where too much or too little human development constrains its reproductive performance.

Factors Related to Nesting Success and Productivity

The amount of developed area within the nesting areas of Swainson's Hawk was not related to its nesting success or productivity (fledglings per nesting attempt). Although the amount of developed area differed significantly between the two study areas (Table 2), it was not a good predictor of reproductive performance (Table 5, Table

6). In fact, there was a positive relationship between nesting success and productivity (fledglings per nesting attempt) and a decrease in the distance to dwellings. While the relationship between reproductive performance and an increase in developed area may seem counterintuitive, other studies of suburban nesting raptors have found similar relationships. High-density urban habitat and road area were greater for highly productive suburban nesting territories of Red-tailed Hawks (*Buteo jamaicensis*) (Stout et al. 2006). Cooper's Hawks nesting in metropolitan Tuscan, Arizona exhibited high nest density, high rates of prey delivery to nestlings, high rates of adult survival, and small home-range size during the breeding season, indicating that this suburban area provided high quality habitat (Mannan et al. 2008). Similarly, Mississippi Kites nesting in suburban areas had higher nesting success and more fledgling per nesting attempt when compared to nesting attempts in rural areas (Parker 1996). However, Red-shouldered Hawk nesting success and fledging rates were not influenced by the amount of developed areas or the proximity of nest to buildings or roads in suburban areas of central California (Rottenborn 2000).

My results show that some amount of human development did not inhibit the reproductive success of Swainson's Hawks. However, no Swainson's Hawks were observed nesting in the most developed areas of downtown Boise. In addition, a nesting area in which 95% of the area within a 1500m radius of the nest was developed was vacant in 2007, and was occupied but failed early in the 2008 breeding season. These observations suggest that there is a limit to the amount of development Swainson's Hawks can tolerate. A study of Burrowing Owls along an urban development gradient in Florida found that Burrowing Owl productivity increased until development exceeded 45-60%, and then decreased as development exceeded 60% (Millsap and Bear 2000). These owls may have benefited from high prey density around homes, but as development exceeded this threshold, any benefit was offset by human-caused nest failures (Millsap and Bear 2000). This may also be true for suburban nesting Swainson's Hawks in southwest Idaho.

Distance to alfalfa was not a good predictor of nesting success or productivity (fledglings per nesting attempt) in univariate analyses. It did appear in one of the top AICc models for nesting success, but it did not add to the predictive power of the final AICc model. Swainson's Hawks can easily forage >10 km from their nests and have even been shown to forage as far as 22 km from their nests (Estep 1989, Babcock 1995). Additionally, Estep (1989) found that home range size varied greatly according to habitat type around a nest site, and the size of foraging areas varied greatly according to agricultural harvesting practices and timing within home ranges. Values of home range size previously reported for nesting Swainson's Hawks range from 69.0 ha to 8717.7 ha, with home range sizes averaging 886.2 ha to 4038.4 ha (Bechard 1982, Estep 1989, Woodbridge 1991, Babcock 1995); and, on average males have larger home range sizes than females. It is possible that the nesting area radius of 1500m that I used was not large enough to capture the importance of the proximity of nests to potential foraging areas as hawks nesting in the suburban areas may have traveled several kilometers to larger more productive foraging areas in the less developed parts of the study area. However, the nesting area radius was selected to identify important habitat features near nest trees, and was not meant to represent a hawk's home range. Trulio (1997) found that Burrowing Owls continue to reproduce within very urbanized areas as long as certain habitat features are preserved, e.g., tall grass areas for foraging and short grass areas for nesting. In the suburban portion of my study area, I often observed multiple adult Swainson's Hawks foraging in small alfalfa fields that remained intact within the highly-developed areas. It is possible that these small fields provided adequate prey for several nesting Swainson's Hawks. Although I did not frequently observe this behavior, it is also possible that fallow agricultural fields within suburban areas provided some foraging opportunities for hawks. Although fallow fields have been shown to provide important foraging habitat in cultivated areas (Babcock 1995), foraging activity in fallow fields within or adjacent to suburban areas has not been reported in Swainson's Hawks. If development near Boise and Meridian continues these areas may no longer be available. A radio telemetry study focusing on the foraging areas of male Swainson's Hawks during the nesting season may provide vital information about foraging habits and distances traveled by hawks within highly-developed areas. These data are likely to point to the importance of maintaining small patches of foraging habitat within developed areas.

Distance to water and the amount of uncultivated area within nesting areas where significant predictors of nesting success and productivity (fledglings per nesting attempt), and these two variables were highly correlated. Most of the water features within the study areas were irrigation canals, so it is reasonable to assume that the amount of uncultivated area increased with increased distance to water. Why this is important for nesting Swainson's Hawks is unclear. The irrigation canals in the study areas were often associated with mature trees, which usually occurred in linear stands along the canal banks. Trees within these linear stands may be more protected from strong winds than lone trees. Tree species may be an important factor to consider as well. Results from a study on Red-shouldered Hawks and Red-tailed Hawks found that the diameter of the branches supporting nests was related to increased nesting success (Bednarz and Dinsmore 1982). Dijak et al. (1990) also found that support branch diameter, as well as tree height and DBH were related to increased nesting success in Red-shouldered Hawks. They also found that the density of trees surrounding the nest tree can influence nesting success, and they suggested that nest trees located in denser groups may be more protected from wind, aerial predation, and disturbance from the ground. In southwest Idaho, tree stands along irrigation canals are frequently composed of black locusts and cottonwoods, which were the two most commonly used nest trees in my study. These two tree species are sturdy and the large forked branches provide stable sites for supporting nests. Nests built in lone trees in the study area, especially in uncultivated areas, are frequently built in elm trees (U.S. Geological Survey, Snake River Field Station, unpublished data). Elms are relatively short and are less sturdy than locusts and cottonwoods. Their branches have a more horizontal orientation and are smaller in diameter, making them unstable nest substrates. Elm trees were the third most commonly used nest tree in my study, and nine nesting attempts occurred in elm trees in the Kuna-Melba study area, while only two nesting attempts in the Boise-Meridian study area occurred in elms trees (Table 4). It is possible that the distance to water variable was a strong predictor of nesting success in my study because water was associated with the location of more stable and protected nest trees, as observed in other raptor species (Bednarz and Dinsmore 1982, Dijak et al. 1990).

My results suggest that mature tree stands associated with irrigation canals are important features for nesting Swainson’s Hawks. Some irrigation canals have riparian and/or wooded buffers on either side. These canals are an important source of nesting substrates for breeding Swainson's Hawks in southwest Idaho. Other irrigation canals do not have any vegetation along the banks, and are therefore a less valuable habitat resource for nesting hawks. Mature trees growing along these canals may be less at risk for development than trees associated with small farms. As small farms are converted into subdivisions, most mature trees associated with farm houses are removed. Land developers usually remove all mature trees, build a subdivision, and then re-landscape the area. Young trees planted during re-landscaping of these areas can take over 20 years to provide an adequate substrate for a Swainson's Hawk nest. This time span may be too great to support current numbers of breeding Swainson's Hawks in the area.

Despite the fact that suburban nesting Swainson's Hawks produced smaller broods than hawks nesting closer to agricultural areas, the overall high reproductive performance in my study indicates that the population of Swainson's Hawks in these two study areas may be relatively stable at this time. It is also possible that when an individual's life time reproductive performance is considered, the tradeoff of having consistently successful nesting attempts in a suburban area may outweigh the benefit of having larger broods in agricultural areas. However, if Southwest Idaho experiences another boom in development, Swainson's Hawks nesting in or near suburban areas may be subject to increased reproductive constraints. Also, it is important to understand the limitations of my study before making any assumptions on the long-term viability of the population of Swainson's Hawks in southwest Idaho. As with any short-term study, I only studied the reproductive performance of this species in a relatively small area for a two-year period. It is possible that the reproductive rates during the two years of my study are not a true reflection of the productivity of this population. It is only through long-term monitoring that we can understand the true population dynamics of a species. Furthermore, we have no data on survival during the post-fledging period and during migration, or on recruitment rates of young into the breeding population. While the reproductive performance of Swainson's Hawks was high during my study, if the young produced do not survive to reach adulthood and are not incorporated into the breeding population, this population of Swainson's Hawk will eventually decline as breeding adults inevitably succumb to old age. While these Swainson's Hawks seem to be tolerating, and perhaps adapting to current levels of human disturbance and development, further studies are needed to better understand how these birds are affected by increased human development and other changes in land use patterns. It is essential to understand what habitat features need to be maintained in order for Swainson's Hawks to thrive in southwest Idaho, as well as across their breeding range.

To protect Swainson's Hawk nesting habitat within developing areas of southwest Idaho, I recommend the protection of tree stands along irrigation canals. I also recommend emphasizing the importance of leaving mature trees within residential developments as agricultural areas are developed. Some species of raptors can benefit from the construction of artificial nesting structures. Land managers often look to this technique as a way of increasing nesting substrates in areas with few natural substrates, or mitigating the loss of natural substrates. However, Swainson's Hawks are reluctant to nest on artificial structures, and the addition of artificial structures in at least one study had no effect on Swainson's Hawk nesting density (Schumtz et al. 1984). Of >500 Swainson's Hawk nesting attempts recorded in and adjacent to my study area, only four nesting attempts occurred on human made structures (U.S. Geological Survey, Snake

River Field Station, unpublished data). One nest (3 attempts) was on a power pole and the other (1 attempt) was on an artificial platform. Management techniques that may be more effective at increasing and/or protecting nesting substrates include tree planting and providing support structures for wind damaged or dead trees.

In addition to protecting suitable nesting substrates, it is critically important to leave potential foraging areas intact within suburbanizing areas. Suburban areas devoid of suitable foraging areas will not be able to support nesting Swainson's Hawks. Maintaining small agricultural areas within developing areas will provide important foraging habitat in close proximity of nest sites. This may reduce the travel time to foraging areas, allowing for more frequent prey deliveries, and may ultimately lead to higher brood size at fledging. Telemetry studies will help to identify critical foraging habitat in areas that have already been developed, as well as lead to a better understanding of what types of areas are the most important for foraging hawks.

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Table 1. Nesting success and productivity of Swainson's Hawk by study area in southwestern Idaho, 2007 - 2008. Sample sizes are in parentheses.

Study Area and Year	Percent Laying Pairs Successful	Brood Size at Fledging	Number Fledged per Laying Pair	Total Fledged
Boise-Meridian				
2007	95.0 (20)	1.79 (19)	1.70 (20)	34
2008	81.3 (16)	2.38 (13)	1.94 (16)	31
Both Years	88.9 (36)	2.03 (32)	1.81 (36)	65
Kuna-Melba				
2007	61.9 (21)	2.38 (13)	1.48 (21)	31
2008	82.4 (17)	2.57 (14)	2.12 (17)	36
Both Years	71.1 (38)	2.48 (27)	1.76 (38)	67

Table 2. Land use and crop types within a 1500 m radius of 74 Swainson's Hawk nests in southwestern Idaho, 2007-2008. Values are reported as mean (range) percent of area within a 706.8 hectare nesting buffer.

Land Use Category	Boise-Meridian	Kuna-Melba
% Developed*	72.6 (39.8-94.0)	11.9 (3.3-44.0)
% Alfalfa*	4.2 (0.0-15.9)	25.2 (1.0-48.8)
% Pasture – Fallow	15.4 (1.1-33.5)	13.2 (0.0-33.2)
% Grain*	1.0 (0.0-10.7)	5.2 (0.0-20.1)
% Corn*	2.4 (0.0-16.7)	19.3 (0.0-51.1)
% Other Crop*	0.7 (0.0-6.7)	2.0 (0.0-9.7)
% Uncultivated Land*	0.0 (0.0-0.0)	19.6 (0.0-86.5)
% Recreational Area*	2.0 (0.0-8.0)	0.6 (0.0-9.7)

* T-tests show significant difference ($P < 0.05$) between study areas

Table 3. Summary of habitat data at and around Swainson's Hawk nests by study area, 2007 and 2008. Nest tree height, nest height and diameter at breast height (DBH) measured to the nearest 0.1 meter. All other values measured to the nearest meter.

Habitat Parameter	Boise-Meridian	Kuna-Melba
Nest Tree Height	21.4 (10.0-34.9)	19.9 (9.9-32.8)
Nest Height	17.8 (7.1-29.6)	15.9 (5.4-29.1)
Nest tree DBH	2.9 (1.0-6.2)	2.7 (0.8-5.1)
Distance to Alfalfa*	725.0 (2.0-3640.0)	198.5 (2.0-1500.0)
Distance to Dwelling*	50.2 (10.0-220.00	229.3 (10.0-1400.0)
Distance to Road	51.2 (5.0-285.0)	61.9 (2.0-390.0)
Distance to Water*	269.6 (2.0-1000.0)	1631.2 (2.0-7900.0)

* T-tests show significant difference (P <0.05) between study areas

Table 4. Nest tree species used by Swainson's Hawks by study area, 2007-2008.

Nest Tree Species	Boise-Meridian	Kuna-Melba
Cottonwood (*Populus spp.*)	11	15
Elm (*Ulmus spp.*)	2	9
Fir (*Abies spp.*)	0	1
Black Locust (*Robinia psuedoacacia.)*	14	7
Maple (*Acer spp.*)	3	3
Pine (*Pinus spp.*)	0	1
Silver Poplar (*Populus alba*)	1	0
Willow (*Salix spp.*)	5	0
Other Exotic	0	1

Table 5. Results of univariate logistic regression procedures predicting nesting success of Swainson's Hawks in southwestern Idaho, 2007-2008.

Variable	Parameter Estimate	SE	t-ratio	P-value	Odds Ratio
Intercept	1.956	0.378	26.786	<0.0001	
% Uncultivated	-0.041	0.012	10.877	0.001	0.960
Intercept	2.057	0.389	27.950	<0.0001	
Distance to Water	-0.001	0.0002	10.791	0.001	0.999
Intercept	1.787	0.351	25.901	<0.0001	
Distance to Dwelling	-0.002	0.001	6.098	0.013	0.998
Intercept	-1.196	1.082	1.222	0.269	
Nest Tree Height	0.139	0.059	5.545	0.019	1.149
Intercept	0.017	0.595	0.001	0.978	
% Pasture/Fallow Field	0.109	0.047	5.298	0.021	1.116

Table 6. Top AICc models predicting nesting success for Swainson's Hawks in southwestern Idaho considered for selection as final AICc model.

Model Parameters	AICc	∆i	Wi	Evidence Ratio
Distance to Alfalfa + Distance to Water	58.8879	0.00000	0.13415	1.00000
Distance to Water	59.0050	0.11702	0.12653	1.06026
Tree Height + Distance to Water	59.7832	0.89529	0.08574	1.56562
Percent Alfalfa + Distance to Water	59.8028	0.91488	0.08490	1.58002
Percent Pasture/Fallow + Distance to Water	60.1607	1.27273	0.07099	1.88960

Table 7. Results of univariate logistic regression procedures predicting productivity (number of young fledged per nesting attempt) of Swainson's Hawks in southwest Idaho. 2007-2008.

Variable	AICc	Parameter Estimate	Units	Odds Ratio	95% LCL	95% UCL	p-Value
Distance to Water	173.183	-0.00033	100	0.94541	0.94551	0.98973	0.0045
% Uncultivated	174.608	-0.0266	5	0.87548	0.79852	0.95987	0.0046
Distance to Dwelling	180.641	-0.00149	10	0.098516	0.97080	0.99974	0.0461
% Pasture/ Fallow	180.754	0.0520	5	1.29701	1.03661	1.62282	0.0229

Table 8. Reproductive performance in studies of Swainson's Hawks across their breeding range.

Location	Nesting Attempts	Percent Successful	Number Fledged Per Laying Pair	Brood Size at Fledge	Source
SE Washington	48	81.3	1.50	1.85	Fitzner (1978)
NE Colorado	119	54.6	1.19	2.18	Olendorff (1975)
Saskatchewan, Canada	1561	70.4	1.50	1.91	Schmutz et al (2001)
SE Washington	96	-	1.11	-	Bechard (1983)
North Dakota	270	64.0	1.55	2.40	Gilmer and Stuart (1984)
SE New Mexico	36	81.0	1.67	1.94	Bednarz (1988)
New Mexico	35	82.9	1.57	1.88	Rodriguez-Estrella (2000)
NE California	724	60.9	1.23	2.01	Briggs (2007)
Yolo Co., CA (rural)	492	82.1	1.35	1.64	England et al. (1995)
San Joaquin Co., CA (rural)	60	80.0	1.38	1.73	England et al. (1995)
Davis, CA (suburban)	31	70.9	1.16	1.64	England et al. (1995)
Stockton, CA (suburban)	44	64.7	1.06	1.64	England et al. (1995)
Boise/Meridian, ID (suburban)	36	88.9	1.81	2.03	This study
Kuna/Melba, ID (rural)	38	71.1	1.76	2.48	This study

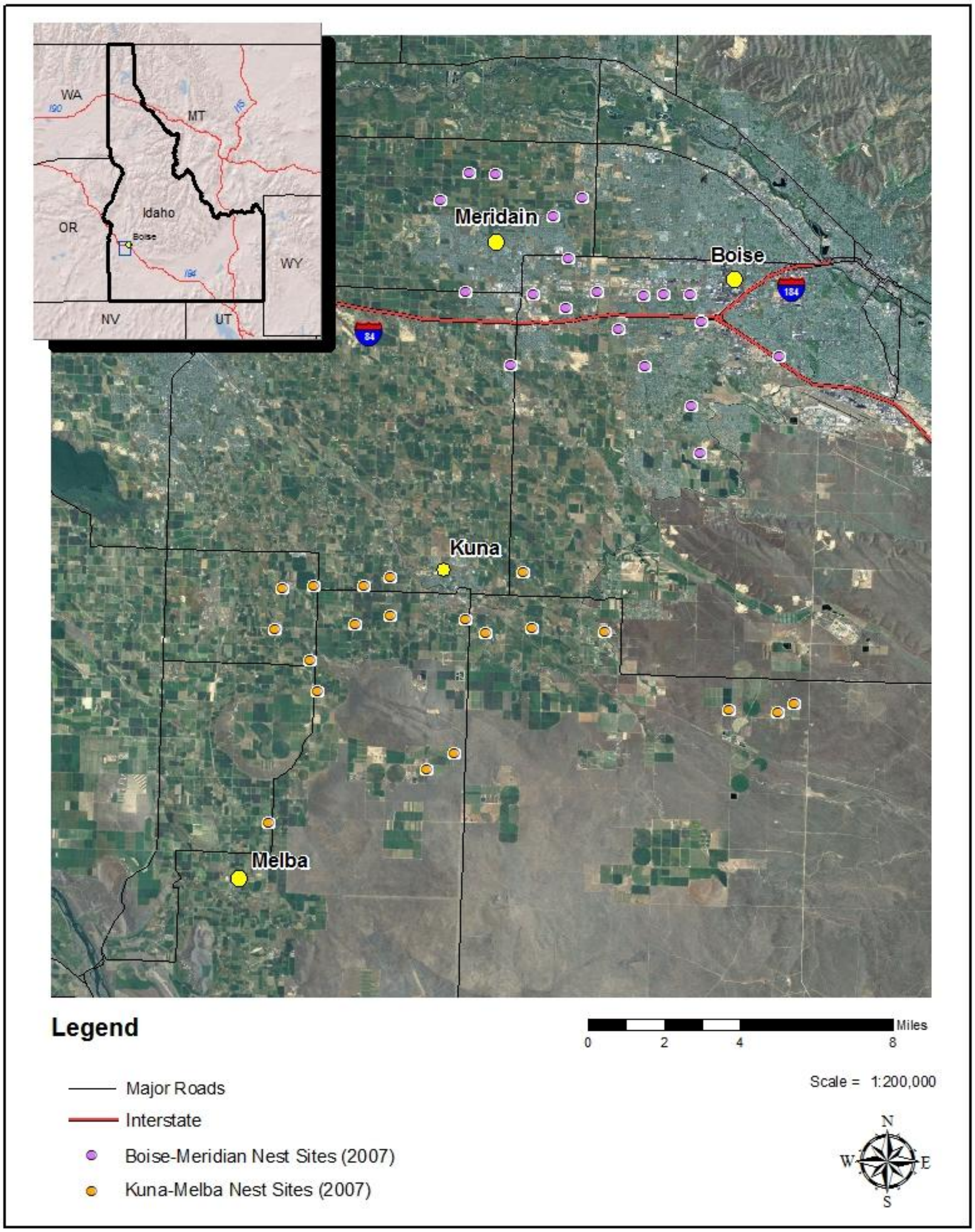

Figure 1. Map of study areas

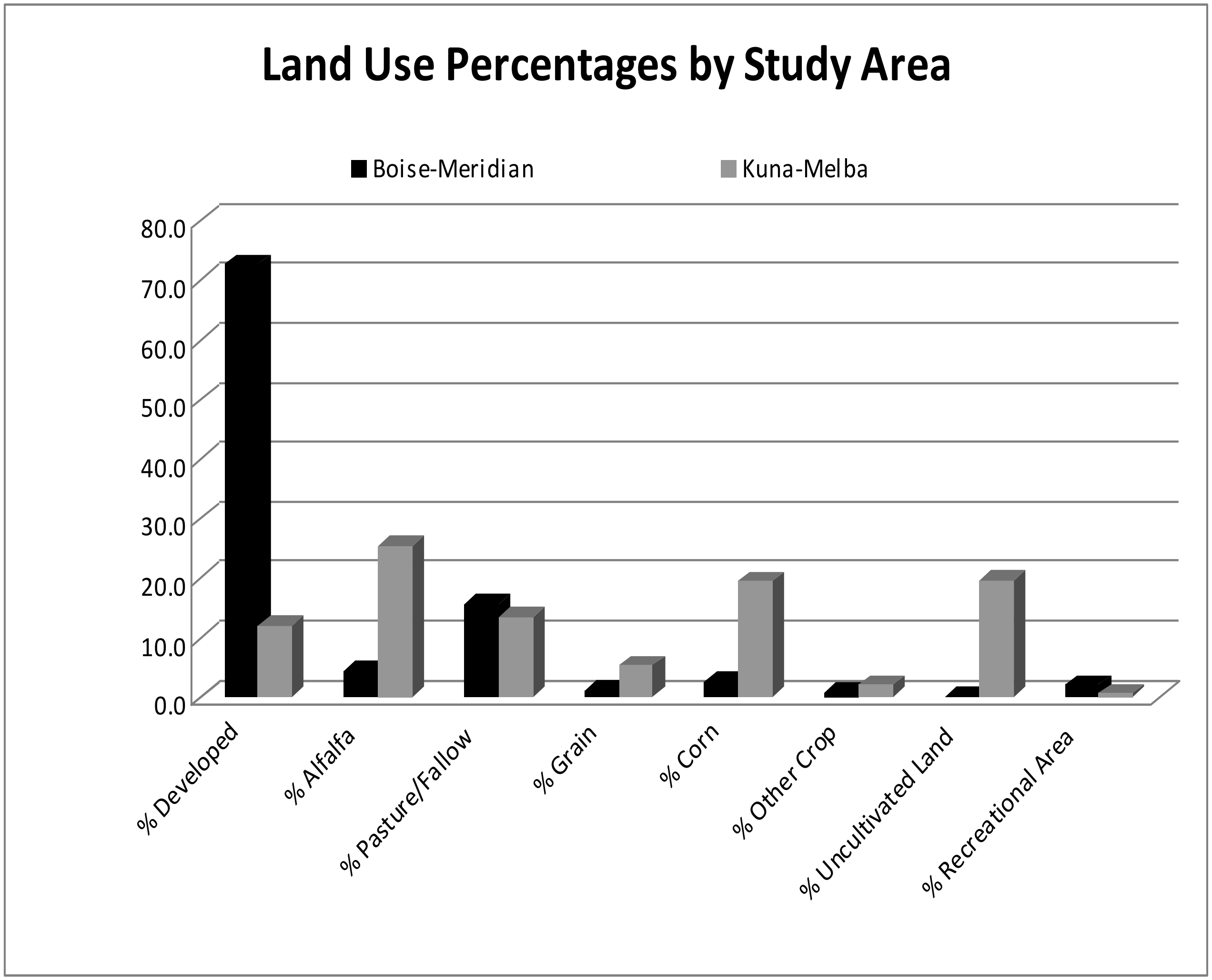

Figure 2. Average land use percentages by study area in southwest Idaho 2007-2008.

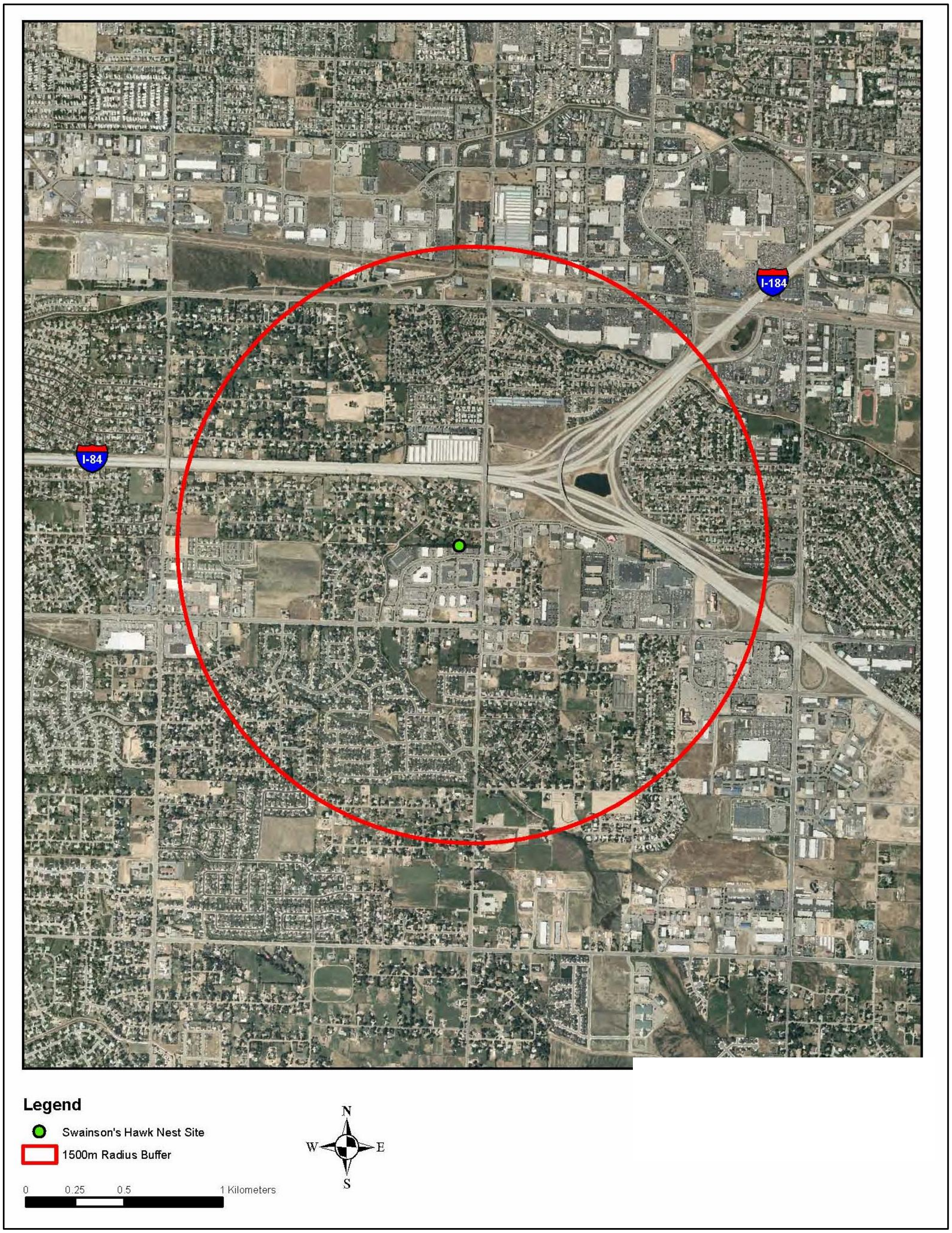

Figure 3. Swainson’s Hawk nesting area with high suburban land use typical of the Boise-Meridian study area.

Figure 4. Swainson's Hawk area with high agricultural land use typical of the Kuna-Melba study area.

APPENDIX A

List of Urbanization Gradient Definitions from Least Developed to Most Developed

Wildlands - Predominantly unsettled areas that may occasionally include dwellings, especially at large scales.

Exurban and rural – Areas which are sparsely settled by individual homesteads, recreational developments, small towns, and villages. Unsettled land is much more abundant than settled land, but the actual pattern of settlement can vary widely. Settlements in **exurban** areas are surrounded by a natural matrix, and those in **rural** areas are surrounded by an agricultural matrix.

Suburban - Characterized by moderate-density to high-density, single-family housing with lot sizes of 0.1 to 1.0 ha. Lawns and gardens are common, and basic services, light industry, and multi-family housing are interspersed with the typical single-family dwellings. Most buildings in suburban areas are single or double-storied.

Urban - Dominated by buildings and building density is high, with many buildings designed for commerce, service, and industry. Single-family homes are rare and typically densely packed with little garden or lawn space. Multi-family housing and multi-storied buildings characterize these areas. Adapted from Marzluff et al. 2001

APPENDIX B

Population increase from 1990-2008 within the cities of Boise and Meridian, the town of Kuna, and Ada County Idaho

	1990	2000	2002	2004	2006	2008	Increase from 2000-2008
Boise	125,738	185,787	193,085	200,062	211,473	214,490	**28,703**
Meridian	9,596	34,919	39,744	47,690	66,565	73,040	**38,121**
Kuna	1,955	5,382	7,386	9,696	12,641	14,830	**9,448**
Ada County	205,775	300,904	323,161	346,212	383,314	402,550	**101,646**

Source: www.compassidaho.org

APPENDIX C

Habitat and Nest Tree Measurements of Swainson's Hawk Nesting Areas by Study Area in Southwestern Idaho, 2007-2008

BOISE-MERIDIAN STUDY AREA

Nesting Area	Year	Success	Productivity	Tree Species (Latin)	Tree Species (Common)	Tree Height	Nest Height	DBH	Nest Position	Tree Location	Dist to Alfalfa	Dist to Dwelling	Dist to Road	Dist to Water
B1	2007	Yes	1	*Populus spp.*	cottonwood	23.3	14.5	1.50	diagonal	line	820	50	70	610
B2	2007	Yes	2	*Salix spp*	williow	15.6	7.1	.	diagonal	single	1725	218	285	2
B2	2008	Yes	3	*Salix spp*	willow	16.8	10.6	1.50	main	single	22	218	285	2
B3	2008	Yes	3	*Populus spp.*	cottonwood	23.6	18.0	.	diagonal	grove	25	73	42	10
B3	2007	Yes	1	*Ulmus spp.*	elm	21.2	17.5	2.14	diagonal	grove	160	10	15	75
B4	2008	No	0	*Robinia psuedoacacia*	black locust	.	.	2.78	diagonal	line	3640	10	30	5
B5	2007	Yes	2	*Robinia psuedoacacia*	black locust	23.5	20.8	1.39	diagonal	line	1000	10	40	5
B5	2008	Yes	1	*Robinia psuedoacacia*	black locust	23.4	21.1	1.97	diagonal	line	1000	10	40	5
B6	2008	Yes	1	*Populus spp.*	cottonwood	19.5	24.1	2.02	main	line	610	15	40	200
B6	2007	Yes	2	*Salix spp*	willow	16.0	11.2	3.00	diagonal	grove	10	75	115	5
B7	2007	No	0	*Robinia psuedoacacia*	black locust	12.6	18.7	2.31	main	line	150	20	65	10
B7	2008	Yes	2	*Robinia psuedoacacia*	black locust	21.2	27.5	1.88	dianonal	line	395	20	65	10
B8	2007	Yes	3	*Populus spp.*	cottonwood	18.2	14.4	1.52	main	line	1010	45	65	935
B8	2008	Yes	3	*Robinia psuedoacacia*	black locust	19.8	17.3	1.56	main	grove	930	15	75	850
B9	2007	Yes	1	*Robinia psuedoacacia*	black locust	15.1	12.4	1.25	diagonal	line	750	10	20	140
B10	2007	Yes	2	*Acer spp*	maple	20.4	16.2	.	diagonal	grove	50	20	35	140
B10	2008	Yes	2	*Acer spp*	maple	20.4	16.2	.	diagonal	grove	2	20	35	140
B11	2007	Yes	3	*Robinia psuedoacacia*	black locust	20.1	17.0	2.96	diagonal	grove	2550	20	15	1000
B11	2008	Yes	2	*Robinia psuedoacacia*	black locust	18.0	14.7	2.96	main	grove	2200	20	15	1000

B12	2007	Yes	2	*Robinia psuedoacacia*	black locust	20.4	16.1	2.04	main	line	1250	60	40	300
B12	2008	Yes	3	*Robinia psuedoacacia*	black locust	16.6	15.6	1.74	main	line	230	10	55	300
B13	2007	Yes	2	*Robinia psuedoacacia*	black locust	20.3	16.4	1.04	main	gove	250	20	45	145
B13	2008	Yes	3	*Robinia psuedoacacia*	black locust	20.3	16.4	1.04	main	gove	1475	30	45	145
B14	2007	Yes	2	*Populus spp.*	cottonwood	33.0	29.6	6.15	diagonal	line	275	60	5	950
B14	2008	No	0	*Populus spp.*	cottonwood	33.0	29.6	6.15	diagonal	line	280	60	5	950
B15	2007	Yes	1	*Populus alba*	silver poplar	17.5	15.0	1.81	diagonal	grove	390	30	10	30
B16	2007	Yes	1	*Populus spp.*	cottonwood	27.1	18.0	3.91	main	single	10	15	25	30
B16	2008	No	0	*Populus spp.*	cottonwood	27.1	18.0	3.91	main	single	940	15	25	30
B17	2007	Yes	2	*Salix spp*	willow	14.7	12.3	4.55	horizontal	line	50	210	18	2
B18	2008	Yes	3	*Robinia psuedoacacia*	black locust	15.3	13.3	2.23	diagonal	line	10	45	80	10
B18	2007	Yes	2	*Acer spp*	maple	27.0	24.0	5.90	diagonal	line	125	22	8	65
B19	2007	Yes	2	*Ulmus spp.*	elm	10.0	8.3	0.98	diagonal	grove	60	65	30	70
B19	2008	Yes	3	*Salix spp*	willow	26.0	18.7	4.58	diagonal	grove	1200	220	15	55
B20	2007	Yes	2	*Populus spp.*	cottonwood	34.9	29.2	5.95	diagonal	grove	1050	15	10	600
B20	2008	Yes	2	*Populus spp.*	cottonwood	34.9	29.2	5.95	diagonal	grove	850	20	10	580
B21	2007	Yes	1	*Populus spp.*	cottonwood	23.0	14.1	.	diagonal	line	640	30	65	300

KUNA-MELBA STUDY AREA

Nesting Area	Year	Success	Product-ivity	Tree Species (Latin)	Tree Species (Common)	Tree Height	Nest Height	DBH	Nest Position	Tree Location	Dist to Alfalfa	Dist to Dwelling	Dist to Road	Dist to Water
K1	2007	No	0	*Populus spp.*	cottonwood	17.5	14.9	2.27	diagonal	grove	850	20	2	7350

K2	2007	No	0	*Pinus spp.*	pine	13.2	12.4	1.30	diagonal	single	40	985	53	5420
K2	2008	No	0	*Pinus spp.*	pine	13.2	12.4	1.30	diagonal	single	250	985	53	5420
K3	2007	Yes	1	*Populus spp.*	cottonwood	18.1	14.5	3.45	diagonal	line	1500	175	390	7900
K3	2008	No	0	*Populus spp.*	cottonwood	16.7	12.3	3.43	main	line	1245	160	2	7830
K3	2007	No	0	*Ulmus spp.*	elm	10.7	8.8	1.62	horizontal	single	1365	160	2	7830
K4	2007	No	0	*Robinia psuedoacacia*	black locust	10.2	9.1	1.30	main	line	10	125	40	75
K4	2008	Yes	2	*Robinia psuedoacacia*	black locust	9.9	5.4	0.93	main	line	48	122	3	35
K5	2007	Yes	3	*Populus spp.*	cottonwood	32.8	29.1	4.50	diagonal	line	30	35	5	410
K5	2008	Yes	3	*Robinia psuedoacacia*	black locust	15.2	11.7	1.00	main	line	12	110	2	380
K6	2007	Yes	2	—	unknown exotic	26.0	22.5	.	horizontal	grove	20	10	20	35
K7	2007	Yes	2	*Populus spp.*	cottonwood	29.2	22.7	3.76	diagonal	line	25	20	2	85
K7	2008	Yes	3	*Populus spp.*	cottonwood	29.2	22.7	3.76	diagonal	line	10	20	2	85
K8	2007	Yes	3	*Populus spp.*	cottonwood	27.9	21.3	3.47	diagonal	grove	50	175	5	215
K8	2008	Yes	3	*Populus spp.*	cottonwood	26.6	19.3	3.43	diagonal	grove	110	175	5	215
K9	2007	Yes	2	*Populus spp.*	cottonwood	21.8	19.2	4.42	diagonal	line	25	15	15	15
K9	2008	Yes	3	*Populus spp.*	cottonwood	21.8	19.2	4.42	diagonal	line	40	15	15	15
K10	2007	Yes	1	*Populus spp.*	cottonwood	20.6	14.2	3.20	diagonal	single	400	35	10	50
K10	2008	Yes	2	*Ulmus spp.*	elm	23.2	17.4	3.72	horizontal	single	2	150	2	200
K11	2007	No	0	*Ulmus spp.*	elm	10.2	7.9	0.90	diagonal	single	510	1200	390	4530
K12	2008	Yes	3	*Abies spp*	fir	17.5	14.0	1.48	main	single	155	25	5	515
K12	2007	No	0	*Robinia psuedoacacia*	black locust	18.7	17.1	2.54	main	line	45	15	5	405

K13	2007	Yes	3	*Populus spp.*	cottonwood	27.5	19.7	3.75	diagonal	grove	50	20	10	250
K13	2008	Yes	3	*Populus spp.*	cottonwood	23.0	14.3	2.41	main	grove	40	15	10	170
K14	2007	Yes	2	*Acer spp*	maple	24.3	20.6	5.10	diagonal	grove	35	30	15	605
K14	2008	Yes	2	*Acer spp*	maple	24.3	20.6	5.10	diagonal	grove	55	30	15	605
K15	2007	Yes	3	*Robinia psuedoacacia*	black locust	12.0	10.3	0.75	main	line	25	140	5	385
K15	2008	Yes	1	*Robinia psuedoacacia*	black locust	16.7	14.3	1.56	main	line	5	320	345	5
K16	2007	Yes	2	*Populus spp.*	cottonwood	30.1	24.9	2.70	diagonal	line	40	60	5	10
K16	2008	Yes	2	*Populus spp.*	cottonwood	30.1	24.9	2.70	diagonal	line	35	60	5	10
K17	2008	Yes	3	*Ulmus spp.*	elm	16.2	13.3	2.40	diagonal	grove	180	90	125	115
K17	2007	No	0	*Robinia psuedoacacia*	black locust	14.4	11.1	2.00	diagonal	line	35	60	105	2
K18	2007	Yes	4	*Ulmus spp.*	elm	13.7	11.8	4.09	diagonal	single	40	150	25	395
K18	2008	Yes	3	*Ulmus spp.*	elm	13.7	11.8	4.09	diagonal	single	40	160	25	1180
K19	2007	Yes	3	*Ulmus spp.*	elm	12.7	8.5	0.90	main	line	80	1390	305	4070
K19	2008	No	0	*Ulmus spp.*	elm	12.9	8.7	0.86	main	line	80	1400	300	4070
K20	2007	No	0	*Acer spp*	maple	24.5	21.5	3.87	diagonal	grove	30	35	15	550
K20	2008	Yes	3	*Ulmus spp.*	elm	28.6	21.4	2.15	diagonal	grove	30	20	15	550

BOISE-MERIDIAN STUDY AREA

Nesting Area	Year	Success	Productivity	% Developed	% Alfalfa	% Corn	% Other	% Pasture/ Fallow	% Recreation	% Un-cultivated	% Grain
B1	2007	Yes	1	64.41	4.72	0.00	0.00	25.95	1.77	0.00	0.00
B2	2007	Yes	2	68.63	0.00	0.00	0.00	22.05	8.02	0.00	0.00
B2	2008	Yes	3	70.84	0.92	0.00	0.00	20.49	6.38	0.00	0.00
B3	2008	Yes	3	85.58	2.67	0.00	0.00	9.06	0.80	0.00	0.00
B3	2007	Yes	1	83.14	2.39	0.00	0.00	11.38	0.67	0.00	0.00
B4	2008	No	0	94.00	0.00	0.00	0.00	1.10	3.97	0.00	0.00
B5	2007	Yes	2	79.25	1.66	0.00	0.00	13.42	2.21	0.00	0.00
B5	2008	Yes	1	80.06	2.34	0.00	0.00	14.27	2.13	0.00	0.00
B6	2008	Yes	1	39.82	6.81	16.73	5.75	17.37	1.36	0.00	10.72
B6	2007	Yes	2	53.72	3.17	14.08	4.81	20.84	0.77	0.00	1.61
B7	2007	No	0	71.76	4.69	0.00	0.00	19.79	2.36	0.00	0.00
B7	2008	Yes	2	71.90	1.52	1.32	0.00	21.41	2.61	0.00	0.00
B8	2007	Yes	3	72.26	1.88	0.00	0.00	20.75	3.94	0.00	0.00
B8	2008	Yes	3	75.49	2.37	0.00	0.00	16.67	4.51	0.00	0.00
B9	2007	Yes	1	53.83	6.17	1.86	0.00	33.49	1.41	0.00	0.00
B10	2007	Yes	2	85.22	1.43	0.00	0.00	11.92	1.03	0.00	0.00
B10	2008	Yes	2	85.95	2.90	0.00	0.00	9.18	1.55	0.00	0.00
B11	2007	Yes	3	65.28	0.00	0.00	0.00	26.99	5.21	0.00	0.00
B11	2008	Yes	2	67.27	0.00	0.00	0.00	23.81	5.18	0.00	0.00

B12	2007	Yes	2	88.87	0.47	0.00	0.00	10.25	0.00	0.00	0.00
B12	2008	Yes	3	91.28	0.04	0.00	0.00	7.71	0.01	0.00	0.00
B13	2007	Yes	2	85.70	2.39	0.00	0.00	10.81	0.00	0.00	0.00
B13	2008	Yes	3	88.52	2.67	0.00	0.00	7.20	0.13	0.00	0.00
B14	2007	Yes	2	66.17	4.94	11.08	0.00	14.81	0.91	0.00	0.00
B14	2008	No	0	66.87	15.90	1.13	0.00	12.26	0.91	0.00	0.00
B15	2007	Yes	1	78.14	12.75	0.00	2.49	2.99	1.35	0.00	0.00
B16	2007	Yes	1	70.01	13.20	4.20	0.00	8.72	2.19	0.00	0.00
B16	2008	No	0	71.30	1.23	5.75	4.08	10.44	2.19	0.00	3.50
B17	2007	Yes	2	50.65	9.65	8.38	0.00	28.54	0.78	0.00	0.95
B18	2008	Yes	3	69.74	4.89	2.65	0.00	18.94	0.76	0.00	2.16
B18	2007	Yes	2	67.94	9.94	0.00	0.00	19.77	0.76	0.00	0.00
B19	2007	Yes	2	64.24	9.93	6.31	3.11	3.34	2.42	0.00	7.80
B19	2008	Yes	3	63.17	1.86	9.58	6.68	5.12	2.50	0.00	7.56
B20	2007	Yes	2	81.76	2.95	0.00	0.00	14.53	0.30	0.00	0.00
B20	2008	Yes	2	81.94	3.77	0.00	0.00	11.49	0.30	0.00	1.51
B21	2007	Yes	1	57.54	8.42	2.79	0.00	29.26	0.00	0.00	1.35

KUNA-MELBA STUDY AREA

Nesting Area	Year	Success	Product-ivity	% Dev	% Alfalfa	% Corn	% Other	% Pasture/ Fallow	% Recreation	% Uncultivated	% Grain
K1	2007	No	0	3.33	10.09	0.00	0.00	8.46	0.00	76.32	0.00
K2	2007	No	0	8.11	31.40	0.00	0.00	11.91	0.00	46.82	0.00
K2	2008	No	0	6.88	34.32	0.00	0.00	8.28	0.00	47.06	0.00
K3	2007	Yes	1	3.96	0.99	0.00	0.00	6.96	0.00	86.53	0.00
K3	2008	No	0	4.04	2.48	0.00	0.00	16.36	0.00	75.13	0.00
K3	2007	No	0	3.40	2.42	0.00	0.00	7.44	0.00	83.35	0.00
K4	2007	No	0	11.43	35.66	36.40	1.93	10.41	0.14	0.00	2.62
K4	2008	Yes	2	11.60	32.49	22.90	2.30	14.08	0.14	0.00	10.27
K5	2007	Yes	3	11.99	25.27	26.80	5.91	25.69	0.14	0.00	2.22
K5	2008	Yes	3	12.10	25.86	16.44	0.96	24.05	0.14	0.00	17.62
K6	2007	Yes	2	4.89	25.17	46.72	3.09	6.32	0.00	5.25	5.46
K7	2007	Yes	2	12.54	25.04	46.50	2.37	10.79	0.00	0.00	2.07
K7	2008	Yes	3	13.69	25.75	29.25	5.40	12.09	0.00	0.00	12.18
K8	2007	Yes	3	21.10	21.11	36.73	0.00	13.84	0.00	0.00	6.72
K8	2008	Yes	3	20.91	21.50	37.25	0.00	12.62	0.00	0.00	5.80
K9	2007	Yes	2	4.33	36.54	8.92	0.27	16.10	8.83	20.99	0.00
K9	2008	Yes	3	6.81	34.33	8.99	0.24	8.48	9.72	24.38	1.88
K10	2007	Yes	1	12.19	21.36	51.07	0.60	7.39	0.00	1.37	4.63

K10	2008	Yes	2	13.07	22.21	27.80	9.71	6.81	0.00	1.54	13.01
K11	2007	No	0	13.15	21.07	10.40	0.00	1.34	0.00	53.57	0.00
K12	2008	Yes	3	14.21	19.60	30.57	4.72	11.08	0.00	0.00	16.31
K12	2007	No	0	13.43	19.09	41.14	2.45	11.48	0.00	0.00	11.70
K13	2007	Yes	3	21.92	44.83	3.00	0.00	19.04	0.00	0.00	7.63
K13	2008	Yes	3	20.64	27.28	6.19	6.21	33.18	0.00	0.00	1.39
K14	2007	Yes	2	9.96	26.95	35.36	7.01	17.55	0.14	0.00	2.29
K14	2008	Yes	2	10.92	22.22	28.26	1.79	13.21	0.14	0.00	20.13
K15	2007	Yes	3	4.01	48.48	23.84	4.48	3.98	0.00	9.58	0.00
K15	2008	Yes	1	4.91	31.29	19.43	9.13	5.35	0.00	18.00	8.54
K16	2007	Yes	2	13.41	48.19	18.76	1.54	13.54	0.00	0.00	2.41
K16	2008	Yes	2	13.36	25.44	18.15	0.00	22.48	0.00	0.00	14.63
K17	2008	Yes	3	5.53	17.52	11.51	5.08	11.19	0.00	33.03	11.98
K17	2007	No	0	5.06	32.11	29.30	0.61	11.98	0.00	13.63	4.84
K18	2007	Yes	4	8.45	48.78	11.97	0.00	25.03	0.00	0.00	2.11
K18	2008	Yes	3	8.95	31.17	15.43	0.00	30.97	0.00	0.00	7.76
K19	2007	Yes	3	4.81	12.39	7.06	0.00	0.48	0.00	74.74	0.00
K19	2008	No	0	5.03	4.71	15.24	0.00	0.00	0.00	74.71	0.00
K20	2007	No	0	43.96	26.95	6.49	0.00	17.33	0.85	0.00	0.00
K20	2008	Yes	3	43.71	16.64	6.12	0.00	26.15	0.85	0.00	0.63