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COOPERATIVE FOREST WILDLIFE RESEARCH - ILLINOIS DEER INVESTIGATIONS

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W-87-R-24-27

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FINAL REPORT

Federal Aid Project W-87-R-24-27

Submitted by:

Cooperative Wildlife Research Laboratory, SIUC

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Division of Wildlife Resources
Illinois Department of Natural Resources

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STATE OF ILLINOIS

W-87-R-24-27

Project Period: 1 January 2002 through 30 June 2005

Project: Cooperative Forest Wildlife Research - Illinois Deer Investigations

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NEED: Successful white-tailed deer (*Odocoileus virginianus*) management requires that responsible agencies base management decisions on an appropriate set of data and revise management schemes as new conditions arise on the landscape. Population models are an essential component of any management program, but are only as good as the parameter estimates input to them. Thus, it is important to have accurate and precise measures of population parameters, especially those most sensitive. Because sensitive white-tailed deer population parameters (e.g., recruitment) vary annually and regionally, based on climate, land use, and other factors, estimates of these must periodically be re-evaluated in order to proactively regulate population growth. Identification of future trends in factors affecting the ability of management techniques to realize program goals is also key to successful and proactive wildlife management. One such factor in Illinois is exurban development that potentially limits the amount of land area available to hunters, thus increasing the *de facto* refuge area for deer. Finally, the emergence of chronic wasting disease (CWD) as a herd health and management concern in Illinois makes it imperative that managers better understand determinants of effective contacts relating to disease transmission. Such understanding is required to predict such rates as a key parameter in models designed to predict risk under various herd management strategies and scenarios.

OBJECTIVES:

1. To upgrade the existing Illinois Deer Harvest Analysis and Modeling Program (IDHAMP)) to make it compatible with newer (and future) computer operating systems.

2. To improve deer population modeling precision for southern Illinois counties by providing estimates of fawn recruitment to 6 months and 1 year of age.

3. To determine the effects of ex-urban development on deer vulnerability to harvest and the potential for increased *de facto* refugia to compromise herd management strategies.

4. To improve CWD models and risk assessment in Illinois by estimating effective contact rates.

EXECUTIVE SUMMARY

Segment 27 of Illinois Department of Natural Resources (IDNR) Federal Aid Project W-87-R (Cooperative Forest Wildlife Research – Illinois Deer Investigations) is the final year of a 4-year project. The original grant proposal was amended in March 2003 (Segment 25) to discontinue Study 1 and Study 2, Job 2.4, and also to add Study 4. Therefore, this project final report covers all the jobs remaining under Studies 2, 3, and 4. Objectives of these jobs were fulfilled, with one exception (Job 3.1 -- Human development and privatization) due to very limited availability of updated data regarding the locations of exurban dwellings. The results of Job 3.1 were to be the foundation for Job 3.2 (Identifying areas of potential conflict). Because few updated data sets were available, and because we found little change in the amount of deer habitat near exurban dwellings in the counties from which we did receive updated data, we focused our efforts for Job 3.2 on our field study area near Carbondale in Jackson County. Within this study area, we were able to directly assess the change in exurban development (>16% increase in dwellings from 2000 to 2004) and used deer location data to produce a habitat use model capable of comparing the pattern of deer habitat utilization with the pattern of exurban development to identify areas of potential human-deer conflict.

Study 1. Population Modeling of the Illinois Deer hear: Updating the Illinois Deer Harvest Analysis and Modeling Program (IDHAMP)

Job 1.1. Determination of appropriate format.–Completed Segment 21.

Job 1.2. Translation of IDHAMP into the updated format.–Inactive.

Job 1.3. Analyze and Report.–Inactive.

Study 2. Population Ecology of White-tailed Deer in Illinois

Study 2 comprised 5 objectives in 5 jobs, and the results were analyzed and reported in Job 2.5 (Analysis and Report). Job 2.4 was discontinued when the grant proposal was amended in Segment 25. We were able to successfully fulfill Jobs 2.1-2.3, as described below. Products of Job 2.5 consist of this Final Performance Report and attached manuscripts, theses, and related products.

Job 2.1. Estimate annual recruitment.–The objective was to obtain reliable and precise estimates of white-tailed deer fawn survival to recruitment in southern Illinois. Because mortality is much higher and more variable during the first months of life, we estimated survival to October 1 (recruitment) and to the end of shotgun hunting season (post recruitment). During 2002-04, 166 fawns were captured and radiocollared in 2 study areas in southern Illinois: 1 in Pope and Johnson counties and 1 in Jackson County. Collared fawns were monitored frequently for mortality signals, and the kill site was inspected immediately after detecting a mortality signal in attempt to identify the cause of death. Data were analyzed in Program MARK (White and Burnham 1999) to estimate survival rates and test for effects of habitat variables and landscape attributes (measured in FRAGSTATS; McGarigal et al. 2002) on fawn survival. Sixty-four mortalities were recorded and the overall survival rate to recruitment was 0.59 (95% CI = 0.51-0.68). Survival to recruitment did not differ significantly between study sites, sexes, or birth periods (during vs. outside the peak). Mortality rates declined with fawn age, and surviving fawns tended to inhabit areas with large, irregular patches of forest. Of the fawns that survived to recruitment, and whose collars remained on and functioning, survival during the post-recruitment period was 0.73 (95% CI = 0.63-0.83).

A master's thesis (Rohm 2005) is provided in lieu of a final report for survival analyses of fawns up to recruitment.

Job 2.2. Estimate cause-specific fawn mortality.–The objective of this job was to estimate the relative contributions of predators, hunting, and non-hunting human causes to fawn mortality. Predation was the leading source of mortality before recruitment (64%), followed by abandonment (8%). Coyotes (*Canis latrans*) were the most prominent predators, accounting for 88% of predation events where the predator could be identified. Only 3 fawns died of nonhunting human causes before recruitment. Of fawns surviving to recruitment, 13% were killed by hunters and 8% by automobiles during the post-recruitment period.

A master's thesis (Rohm 2005) is provided in lieu of a final report for cause-specific mortality of fawns up to recruitment.

Job 2.3. Evaluate precision of population model parameters.–The objective of this job was to determine if harvest-based estimators of deer recruitment are biased and what factors contribute to any observed bias. We compared empirical estimates of fawn summer survival rates (0.59; from Job. 2.1) with rates used in Illinois Deer Harvest Analysis and Management Program (IDHAMP; Roseberry 1995), based on harvest-based estimates of 2002 deer population sizes in Jackson, Johnson, and Pope counties and IDHAMP's density-dependent survival model. We found that fawn survival rates in IDHAMP were very similar to empirical estimates, and adjusting mortality parameters to match empirical estimates led to very little change in population projections. We also found that incorporating realistic annual variations in fawn survival (SD = 0.052) produced relatively little variation in projected deer population trajectories (max CV = 8-16%).

Thus, our findings do not indicate that IDHAMP estimates of deer recruitment are substantially biased.

Study 3. Impacts of Ex-Urban Development and Privatization on Deer Herd Management

Study 3 comprised 5 objectives in 5 jobs, and the results were analyzed and reported in Job 3.5 (Analysis and Report). We were generally able to fulfill the objectives of Study 3, as described below, with the exception that very little recent data on rural dwellings were available for Job 3.1. Thus, our findings for Job 3.1 are tentative. Products of Job 3.5 consist of this Final Performance Report and attached manuscripts, theses, and related products. Following is a summary of the major accomplishments and findings of Study 3.

Job 3.1. Human development and privatization.–The objective was to quantify the extent of ex-urban development in rural areas of Illinois by comparing the current density of human dwellings in selected rural counties with that measured during segment 23 of the previous grant period. Few counties had updated digital or map data available for this analysis. For the 5 counties providing updated data, we found little change in the amount of deer habitat (Roseberry and Woolf 1998) within 274 m of rural dwellings between 2001 and 2005. A greater span of time is needed for updated data to become available to adequately address this objective.

Job 3.2. Identifying areas of potential conflict.–The objective of this job was to identify sites of potential human/deer conflict and areas where ex-urban development and/or privatization may have greatest impact on deer populations. In Job 3.1, we found a severe lack of updated rural dwelling data available, and determined that there was little change in the amount of deer habitat near dwellings in the counties for which we were able to obtain data. Therefore, we focused our effort in this job on our study area outside Carbondale, which has experienced rapid exurban development and for which we have obtained a substantial amount of data on deer distribution and movements (see Job 3.5). We used the Penrose distance statistic to characterize the likelihood of deer use across this study area. We found that deer tended to use areas near dwellings less than expected, except where dwellings coincided with forest edges. This combination of factors seemed to be associated with sparse and linear groups of human dwellings, whereas tight clusters of dwellings were more strongly avoided. These results suggest that the spatial pattern of exurban development, as well as the overall amount, is likely to influence the risk of human-deer conflict. In particular, human-deer interaction seems most likely when dwellings are sparse and arrayed linearly.

Job 3.3. Effects on hunter distribution and behavior.–The objectives of this job were to assess the effect of ex-urban development on hunter distribution in a select area of Illinois and develop models that can predict the impacts of rural development on hunter behavior statewide. These objectives were addressed by surveying residents of an exurban area southeast of Carbondale, Illinois. Responses of exurbanites differed from responses of suburban residents of Carbondale reported by Cornicelli et al. (1993, 1996) in that deer were more likely to be observed on exurban than suburban properties, and exurbanites were more tolerant of deer on their property. Exurban residents were more likely than Carbondale residents to desire reduction of the deer population, yet only 19% allowed deer hunting on their properties and hunting pressure on most properties was very low, which was reflected in the very low mortality of adult does in this study area (see Job 3.4). Only about half of hunted properties allowed shotgun hunting. These results imply that exurban development statewide is likely to strongly reduce harvest efficiency and the effectiveness of typical adjustments to recreational harvest (e.g., antlerless permit allocations) for managing deer abundance. A master’s thesis (Storm 2005) is provided in lieu of a final report for this job.

Job 3.4. Effects on deer distribution and populations.–The objective of this job was to use data available on deer movements to investigate their use of the ex-urban landscape. Thirty-seven does, mainly adults, were captured in the exurban study area near Carbondale, and monitored by VHF or global positioning system (GPS) radiocollars. Home range sizes (mean $\pm$ SE = 91 $\pm$ 10 ha) were found to be generally intermediate between published home range estimates for rural and urban/suburban deer. The density of human dwellings in home ranges and core areas of deer was greater in winter (ca. 0.17 dwellings/ha) than during the fawning season (ca. 0.13 dwellings/ha), and dwellings were slightly less dense in deer core areas than in the remainder of their home ranges. Compositional analysis indicated that deer in this study area tended to prefer habitats >100 m from human dwellings. Annual survival rate was 0.91 (95% CI = 0.83-1.0), which is higher than has been reported even for many suburban deer populations. Findings of this job indicate that exurban does near Carbondale frequently use areas near dwellings but do not appear to seek them out as refuges from hunting or sources of winter food. In this study area, does appear to prefer to stay away from dwellings, but this pattern may not pertain to areas with harsher winters or higher hunting pressure where peridomestic sites may be more attractive. A master's thesis (Storm 2005) is provided in lieu of a final report for this job.

Study 4. Modeling and Risk Assessment of CWD in Illinois

Study 4 comprised 2 objectives in 2 jobs, and the results were analyzed and reported in Job 4.2 (Analysis and Report). Products of Job 4.2 consist of this Final Performance Report and an attached manuscript. Following is a summary of the major accomplishments and findings of Study 4.

Job 4.1. Estimate Contact Rates.–The objective was to develop estimates of contact rates based on multiple deer use of specific sites and use these rates to improve predictive models of CWD persistence and spread in Illinois. Because the mode and efficiency of transmission of CWD are unknown, it is not possible to provide estimates of effective contact (i.e., rate at which an infective deer would infect other deer). Rather, we estimated contact rates as an index of potential transmission. Movements of 23 deer (mainly adult does) near Carbondale, Illinois, were monitored by GPS collars for 1 to 14 months. From these data, within-group pairs of deer were distinguished from between-group pairs, and direct and indirect contact rates were estimated. Direct contact rates were ca. 11-fold greater for within-group pairs than between-group pairs, even after accounting for greater home range overlap of within-group pairs. The effect of group membership on indirect contact rates for moderately persistent pathogens (half-lives > 7 d) was almost entirely explained (except in summer) by the degree of home range overlap. These results indicate that home range overlap is not an adequate index of potential direct transmission among deer, but it may be an adequate index for indirectly transmitted pathogens that can persist in the environment. Both direct and indirect contact rates are likely to be responsive to changes in deer density, although indirect contact rates may involve a time lag due to pathogen persistence. If CWD transmission is primarily direct, then it is likely to spread within social groups much faster than between groups, so management efforts focused on particular groups may be efficient. If CWD is indirectly transmitted, then group membership will have a smaller influence on epizootiology and disease spread will be driven by patterns of joint space use. A submitted manuscript (Schauber et al. 2005) is provided in lieu of a final report for this job.

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STUDY 1. POPULATION MODELING OF THE ILLINOIS DEER HERD: UPDATING THE ILLINOIS DEER HARVEST ANALYSIS AND MODELING PROGRAM (IDHAMP)

JOB 1.1. DETERMINATION OF APPROPRIATE FORMAT

Objective: To determine the appropriate format/programming language that (1) will allow IDHAMP to operate in the newer operating systems, and (2) will remain compatible with evolving systems.

This job is COMPLETE and was reported in Segment 21.

JOB 1.2: TRANSLATION OF IDHAMP INTO THE UPDATED FORMAT

Objective: Translation of IDHAMP into a Windows/Windows NT-based program.

Inactive.

JOB 1.3: ANALYZE AND REPORT

Objective: To prepare products from Jobs 1.1 and 1.2, with appropriate documentation, and provide to IDNR personnel.

Inactive.

STUDY 2. POPULATION ECOLOGY OF WHITE-TAILED DEER IN ILLINOIS

JOB 2.1: ESTIMATE ANNUAL RECRUITMENT

Objective: To obtain reliable and precise estimates of white-tailed deer fawn survival to 10-12 months of age in southern Illinois.

Fawn collars were designed to expand and ultimately fall off the animal, so we did not acquire sufficient data to estimate survival rates to 10-12 months of age. However, mortality during the first 6 months is higher and more variable than during any other period of a deer's life. Therefore, we focused survival analyses on the period leading up to the initiation of legal hunting in Illinois (1 Oct), which we will define as recruitment into the huntable population, and the subsequent period to the end of the shotgun deer season (typically by 8 Dec), which we will define as post-recruitment. A Master's thesis (Rohm 2005) is attached in lieu of a final report of the methods, results, and findings of this job pertaining to survival to recruitment. Following is an abstract of that thesis.

Survival of white-tailed deer (*Odocoileus virginianus*) fawns has been quantified throughout much of North America. However, few studies have assessed the influence of environmental factors (e.g., fawn age, birth mass, and habitat structure) on fawn survival. During 2002-2004, 166 fawns were captured and radiocollared in southern Illinois to estimate survival rates, determine causes of mortality, and identify factors influencing fawn survival. A known fates model in program MARK was used to estimate survival rates and compare explanatory models based on AIC_c. Two candidate sets of a priori models were developed to quantify factors influencing fawn survival. Model set 1 contained models constructed from combinations of the following variables age, sex, capture year, study site, birth mass, and birth date relative to the peak parturition period. Model set 2 contained models constructed from habitat metrics obtained from buffered capture locations and calculated in

FRAGSTATS. Sixty-four mortalities were recorded and the overall survival rate was 0.59 (95% CI = 0.51-0.68). Predation was the leading source of mortality (64%) and coyotes were the most prominent predator. For model set 1, model $\{S_{age*year}\}$ had the lowest AIC_c value indicating that the age at mortality varied among capture years. For model set 2, model $\{S_{landscape+forest}\}$ had the lowest AIC_c value and indicated that areas inhabited by surviving fawns were characterized by a few large (i.e., >5 ha) irregular forest patches adjacent to several small non-forest patches, and survival areas also contained more edge habitat than mortality areas. Due to the magnitude of coyote predation, survival areas could have represented landscapes where coyotes were less effective at locating and capturing fawns. Because fawn survival rates vary by habitat and through time, fawn survival studies should be conducted regionally and updated periodically. This study was the first account of habitat characteristics influencing fawn survival. Knowledge of which habitat characteristics affect fawn survival can be used to help managers manipulate landscapes and map fawn mortality risk at large scales. Such a map could help effectively target areas for implementing predator control programs and aid managers in setting deer harvest allocations for management units.

Of the 91 fawns that survived to recruitment, the fates of 8 are unknown due to collars dropping off or no longer producing a signal (Table 1). Of the remaining 83 fawns, survival to the end of shotgun season was ca. 0.73 (95% CI = 0.63-0.83). There was not compelling evidence for variation in post-recruitment survival among years (χ^2 = 2.04, d.f. = 2, P = 0.36). Combining recruitment and post-recruitment survival, cumulative survival of fawns to the end of hunting season was 0.59 x 0.73 = 0.43.

LITERATURE CITED

Rohm, J. H. 2005. Survival of white-tailed deer fawns in southern Illinois. Thesis, Southern Illinois University, Carbondale, Illinois, USA.

Table 1. Fate of white-tailed deer fawns post-recruitment (1 Oct to first Monday after end of shotgun deer season) in southern Illinois, 2002-04.

	Year								
	2002		2003		2004		Total		
Fate	#	Proportion[a]	#	Proportion	#	Proportion	#	Proportion	95% CI
Recruits[b]	25	---	29	---	37	---	91	---	
Unknown fate[c]	3	---	4	---	1	---	8	---	
Unknown death[d]	1	0.045	0	0	0	0	1	0.012	0.00-0.065
Archery harvest	1	0.045	0	0	0	0	1	0.012	0.00-0.065
Shotgun harvest	4	0.182	2	0.08	4	0.111	10	0.12	0.059-0.21
Vehicle Collision	0	0	1	0.04	6	0.167	7	0.084	0.035-0.17
Predation	1	0.045	1	0.04	1	0.028	3	0.036	0.30-0.84
Post-recruitment survivors	15	0.682	21	0.84	25	0.694	61	0.735	0.63-0.83

[a]Of recruits with known fate.
[b]Fawns surviving to October 1.
[c]Fawns whose collars dropped off or signal was lost.
[d]There was evidence that death had occurred but not sufficient evidence to determine cause.

JOB 2.2: ESTIMATE CAUSE-SPECIFIC FAWN MORTALITY

Objectives: To estimate the proportion of fawn mortality attributable to natural causes, non-hunting human causes, and legal hunting.

A Master's thesis (Rohm 2005) is attached in lieu of a final report of the methods, results, and findings of this job pertaining to cause-specific mortality up to 1 October. Post-recruitment mortality data are presented in Table 1. Predation was a much smaller proportion of overall mortality post-recruitment, with only 2 (10.5%) out of 19 known fawn deaths attributable to predators. A total of 13% of recruited fawns were killed by hunters, with only 1 killed during archery season. Vehicle collisions killed an additional 8% of fawns.

LITERATURE CITED

Rohm, J. H. 2005. Survival of white-tailed deer fawns in southern Illinois. Thesis, Southern Illinois University, Carbondale, Illinois, USA.

JOB 2.3: EVALUATE PRECISION OF POPULATION MODEL PARAMETERS

Objectives: To determine if harvest-based estimators of deer recruitment are biased and what factors contribute to any observed bias.

INTRODUCTION

The Illinois deer harvest and management program (IDHAMP; Roseberry 1995) was developed to provide a tool for organizing, displaying, and analyzing Illinois deer harvest data, and to use those data for modeling deer population dynamics. However, the parameter estimates used in IDHAMP for fecundity and nonhunting mortality need to be periodically assessed to maintain accuracy in population estimates (Roseberry and Woolf 1991). Survival of fawns to recruitment has a substantial influence on deer population growth rates and equilibrium densities, yet it can vary over time and change with density. Therefore, we compared fawn survival rates in IDHAMP with empirical estimates, and assessed the effects on incorporating realistic temporal variations in fawn survival rates on deer population projections.

METHODS

We focused this analysis on Jackson, Johnson, and Pope counties, as these areas had been identified as having low fawn:doe ratios in the harvested population. The hypothesis that low fawn survival is the explanation for these low ratios was tested by comparing observed fawn survival rates with the values used by IDHAMP.

The IDHAMP population simulations are based on nonlinear density-dependent relationships between vital rates (mortality and fecundity) and deer abundance. The relationship for mortality rate in IDHAMP is decelerating, i.e., steepest at low deer abundance (Roseberry 1995). Therefore, empirical estimates of fawn survival rates cannot be directly compared with the mortality rate parameter values in IDHAMP, because the IDHAMP parameters (summer fawn mortality rates of 0.23 for males and 0.19 for females) represent intercept values assumed to be correct only for populations at very low density. We used IDHAMP with default parameter values and available harvest data sets to plot population trajectories in Jackson, Johnson, and Pope counties, Illinois, for the period 1980-2002. We then calculated the predicted fawn survival rates for males and females on the basis of model-estimated population size in 2002, and compared them with empirical estimates (from Job 2.1). We also determined what intercept mortality values would need to be in order for the predicted and observed survival rates to match at the relevant population density, and used IDHAMP to project deer population trajectories from 2002-10 with both the default and the new intercept mortality values and typical harvest rates for the period 1998-2002. We did not use the new intercept mortality values to reconstruct past population trajectories because doing so would result in a different final density, and hence a different ending survival rate. Finally, we assessed the effects of temporal fluctuations in fawn survival rates by comparing the deterministic 1980-2002 projections for each county based on default parameter values with the results of projecting the population (n = 10 replicate projections) over the same interval with summer fawn mortality parameters varying annually with a similar standard deviation as observed in field data (0.052; Rohm 2005).

RESULTS

Model-estimated deer abundance increased approximately exponentially for all 3 counties during the 1980s, at annual rates of 11-15%, but tended to level off during the 1990s (Fig. 1A). These trends in model-estimated abundances were generally well matched by the indices of abundance provided in IDHAMP (Fig. 2). Relative to the county-specific carrying capacity (K) parameters in IDHAMP, modeled deer abundances in 2002 were 54% of K in Pope County, and 38% of K in both Jackson and Johnson counties (Fig. 1B). Therefore, harvest appeared to be regulating deer abundance at approximately the optimal levels for high sustained yield. Summer fawn survival rates estimated by IDHAMP at the 2002 population level were slightly above the overall estimate of 0.59 for summer fawn survival rate based on field data (Table 2). To match modeled survival rates with empirical estimates, intercept mortality rates for males and females can be set to 0.22 for Pope County and to 0.25 for Jackson and Johnson counties. This small change in parameter values had very little effect on population projections (Table 3), with projected 2010 abundances based on the altered mortality rates differing from default projections by only 1.2-2.2%. Model projections with time-varying summer fawn mortality rates showed relatively little variation among replicate runs (Fig. 3), with coefficients of variation peaking at only 8% for Jackson and Pope counties and 16% for Johnson county (primarily due to 1 outlying replicate)..

DISCUSSION

The observed fawn:doe ratios for Jackson, Johnson, and Pope counties appear to be consistent with levels expected on the basis of population sizes and density dependent reduction in fawn survival. Fawn summer survival rates in IDHAMP at relevant population levels, particularly for females, were very close to our empirical overall estimate of 0.59, and population projections based on empirical estimates of fawn mortality were very close to projections based on default parameter values. Also, including annual variation in fawn survival in IDHAMP projections generated relatively little variation in population trajectories. Therefore, our findings indicate that, at least for the counties we studied, fawn survival rates used by IDHAMP are not substantially biased and that annual variation in fawn survival has little influence on the precision of population projections.

LITERATURE CITED

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Table 2. Estimates of 2002 fawn summer survival for Jackson, Johnson, and Pope counties, based on model-estimated population abundance and a nonlinear density dependence model from IDHAMP.

	County		
Sex	Jackson	Johnson	Pope
Male	0.65	0.65	0.58
Female	0.61	0.61	0.62

Table 3. Comparison of projected deer abundance in 2010 based on default summer fawn mortality parameters and based on parameters altered to produce 0.59 estimated survival in 2002.

	County		
	Jackson	Johnson	Pope
Default parameters	33,902	25,564	24,892
Altered parameters	33,169	25,045	24,604
Difference (%)	2.2	2.1	1.2

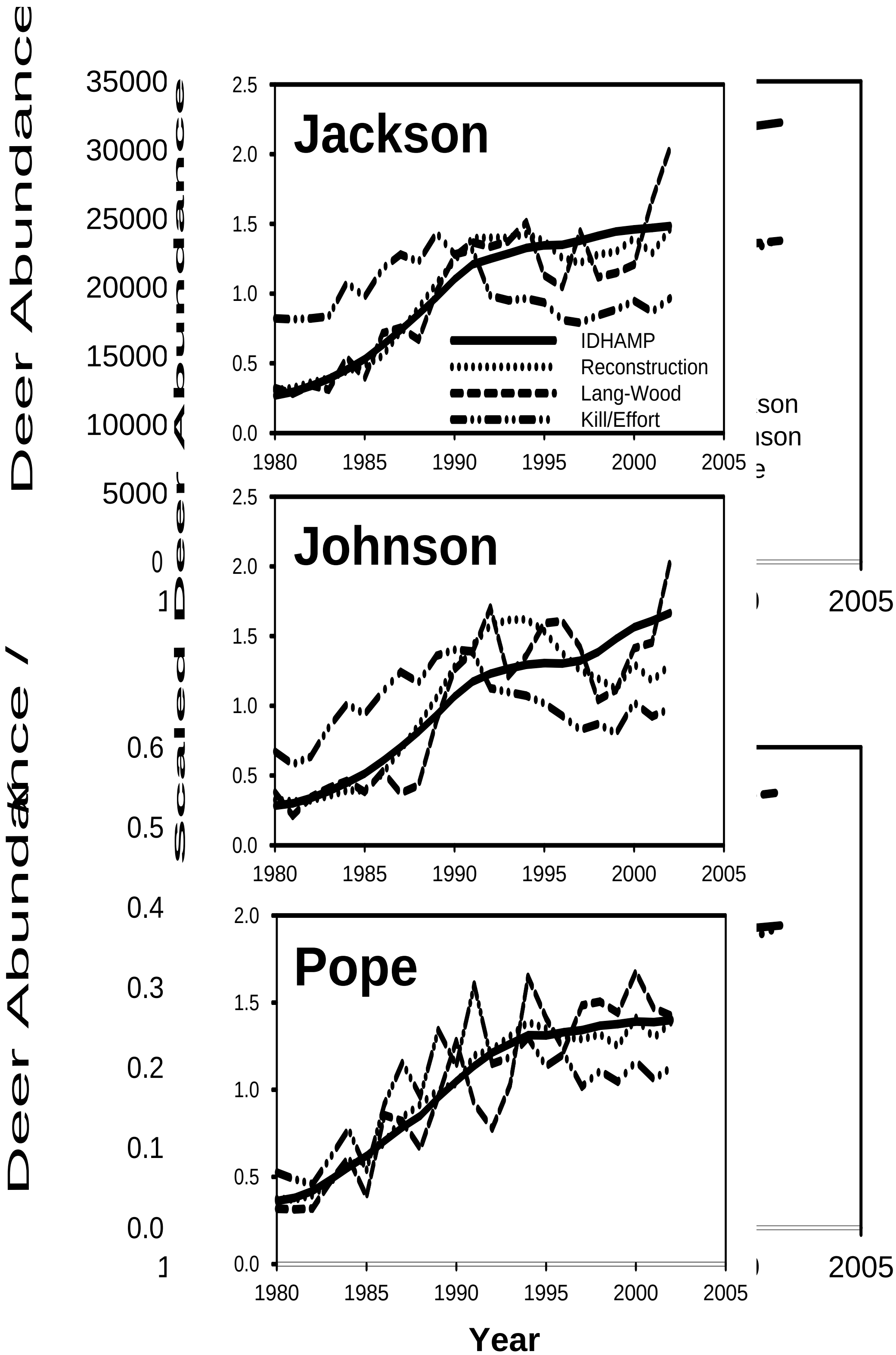

Figure 1. Estimated county-level deer abundance for Pope, Jackson, and Johnson counties, Illinois, 1980-2002, based on IDHAMP. (A) County-level population size and (B) abundance represented as a proportion of county-level carrying capacity (*K*).

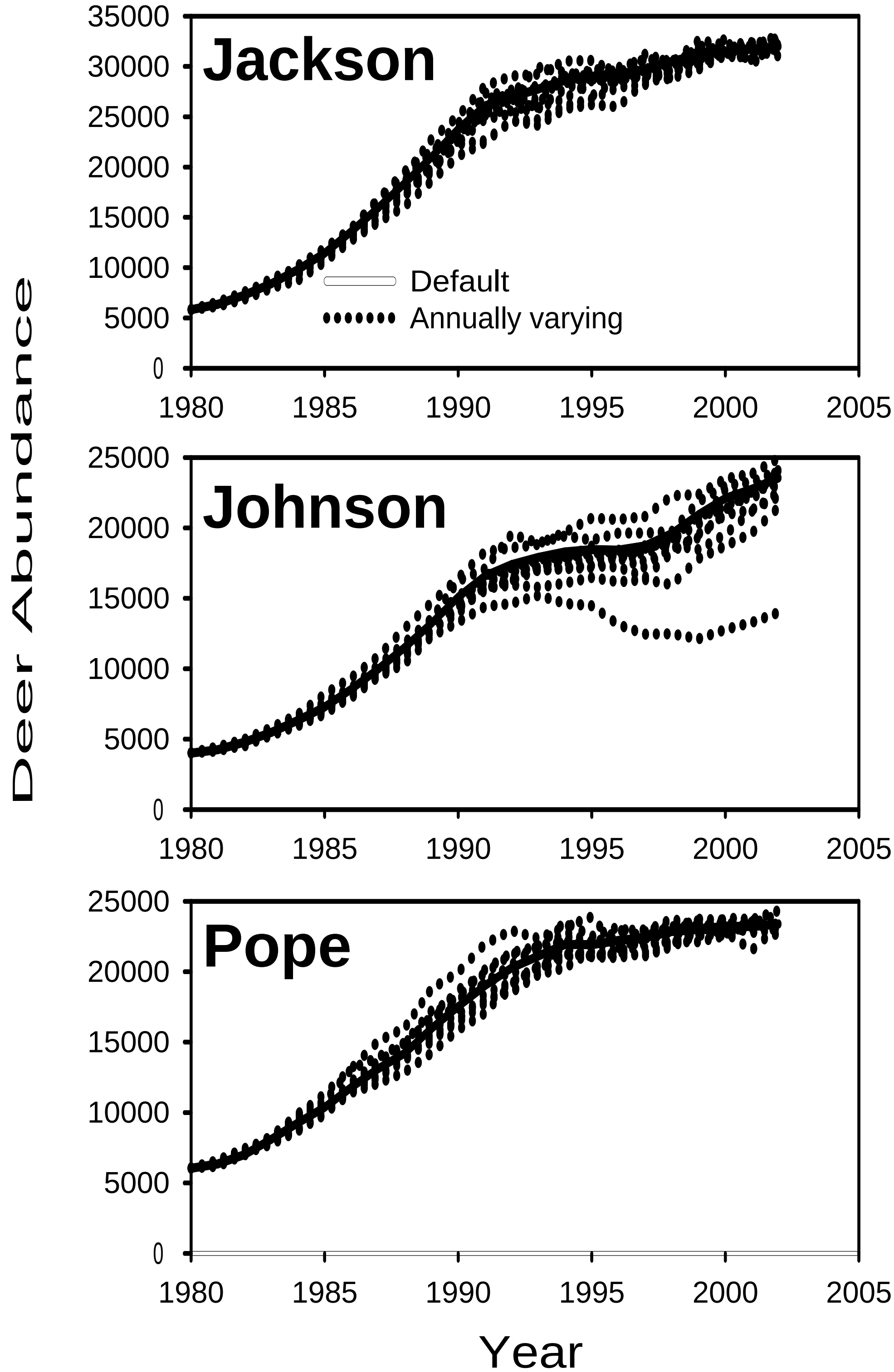

Figure 2.
Qualitative match between IDHAMP estimates of county-level deer abundance and 3 alternative indices: reconstruction, Lang-Wood, and kill per unit effort (Roseberry 1995). Abundance estimates and indices are scaled by their means for each county.

Figure 3. Results of IDHAMP projections of deer abundance trends in Jackson, Johnson, and Pope counties, 1980-2002, with constant default parameter values and annual variation in summer fawn mortality rates.

JOB 2.5: ANALYSIS AND REPORT

Objective: To make recommendations on deer population data collection needs and analysis.

Objectives were met through preparation of quarterly, annual, and this report. Also, periodic meetings were held with IDNR, Division of Wildlife Resources, Forest Wildlife Program staff to discuss findings and project progress.

STUDY 3. IMPACTS OF EX-URBAN DEVELOPMENT PRIVATIZATION ON DEER HERD MANAGEMENT

JOB 3.1: HUMAN DEVELOPMENT AND PRIVATIZATION

Objective: Quantify the extent of human development and privatization in rural areas of Illinois.

INTRODUCTION

Exurban development, characterized by dwelling density and property sizes intermediate between rural and suburban areas (Nelson 1992), is the most rapidly increasing form of land use in the United States (Nelson and Sanchez 2005). Exurban dwellings are often located within quality habitat for wildlife like white-tailed deer (Odell and Knight 2001), potentially increasing the risk of conflict between humans and wildlife. Also, although property sizes in exurbia are often large enough for legal hunting to occur, the proportion of land area in close proximity to dwellings where hunting is highly restricted (274-m radius in Illinois) is greater in exurban than rural areas. Thus, exurban development is associated with reduced deer harvest efficiency in Illinois (Harden et al. 2005). Therefore, understanding trends in the amount of deer habitat influenced by exurban development is important for managers to evaluate the appropriateness of current wildlife population management and adjust tactics in the face of a changing landscape.

METHODS

Counties with greater than 50% of total county deer habitat within the 274 m buffer around ex-urban homes (Harden et al. 2005) were used as sample counties ($n = 36$). We contacted county Emergency Transportation Board coordinators in sample counties to request any new ex-urban structure data in these counties. Data on paper maps were converted into digital form ($n = 1$ county). Structure location data from each county able to supply data ($n = 5$ counties) were entered into a geographic information system (GIS, ArcView 3.3, Environmental Systems Research Institute, Redlands, California, USA).

We created a contiguous buffer with a radius of 274 m around each rural structure in the updated data sets, to represent the area within firearm hunting exclusion zones. For each county, we overlaid the buffered area on the map of 4 deer habitat classes (forage, cover, marginal forage, and marginal cover) developed by Roseberry and Woolf (1998), and determined the change in total area of each class within the buffered area between 2002 data (as reported by Harden et al. 2005) and 2005 data.

RESULTS AND DISCUSSION

Although the changes varied among counties, average change in habitat area within the exclusion zone was positive for all habitat classes, ranging from +0.01 to +1.0% (Table 4). However, variation among counties and small sample size prevents reliable extrapolation to other counties, as indicated by the large standard errors (Table 4). All habitat classes within exclusion zones decreased or were constant in Jasper County, and the area of marginal habitat decreased in Perry County. Otherwise, all changes in deer habitat area within the exclusion zone were positive (Table 4).

Our findings support the notion that the proportion of deer habitat influenced by exurban development continues to increase in many Illinois counties. This increase averaged near 1% over 3 years for quality forage and cover habitats, indicating that the overall change may not be dramatic in the short term. However, the change in the amount of quality habitat within exclusion zones varied greatly among counties, with Peoria County showing increases of 3-4.5%.

A major issue in this analysis was that few counties were able to provide information on dwelling locations, either in digital or paper formats, updated since this study was initiated in segment 23. It is possible that the frequency at which dwelling location data sets are updated is related to the rate at which exurban development is progressing. For example, counties with little exurban development may choose to wait longer periods before updating their data sets. Alternatively, counties with rapid exurban development may choose not to update their data sets because even the updated data would be obsolete in short order. Because of these potential biases, our findings should be interpreted very cautiously with respect to their applicability to counties from which we did not receive data sets.

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Table 4. Change in total area from 2002 to 2005 (expressed as percentage of the 2002 area) of 4 deer habitat classes within a 274 m buffer around rural structures in each sampled county providing data[1].

County	Cover	Forage	Marginal Cover	Marginal Forage
Jasper	-1.58	-2.65	0.00	-2.15
Knox	0.69	1.09	0.00	0.66
Peoria	3.14	4.44	0.02	2.17
Perry	1.47	1.20	0.02	-0.44
Williamson	0.71	0.92	0.00	0.33
Mean	0.89	1.00	0.008	0.11
Std. error	0.76	1.12	0.005	0.71

[1]Counties contacted but which were unable to provide updated data: Adams, Bond, Cass, Clark, Crawford, Cumberland, Effingham, Franklin, Fulton, Gallatin, Hancock, Jackson, Jefferson, Jo Daviess, Johnson, Madison, Marion, Massac, Mercer, Monroe, Morgan, Pulaski, Randolph, Richland, Rock Island, Saline, Scott, Union, Wabash, Washington, and White.

JOB 3.2: IDENTIFYING AREAS OF POTENTIAL CONFLICT

Objective: Identify sites of potential human/deer conflict and areas where ex-urban development and/or privatization may have greatest impact on deer populations.

Given the recent advent of remote sensing and geographic information systems (GIS), several wildlife biologists have developed large-scale models of habitat suitability for white-tailed deer (Roseberry and Woolf 1998, Felix et al. 2002, Miranda and Porter 2003). Although these analyses have provided insight into factors affecting deer density and distribution over large scales, no studies have explicitly predicted likely areas of deer-human interaction based on deer habitat information and human activity. Such information is important for understanding potential risk for deer damage to vegetation, deer-vehicle accidents, and risk of contracting zoonotic diseases.

Because we were only able to obtain updated data on dwelling locations from a small number of Illinois counties, and because the change in the amount of deer habitat near dwellings was very small in those counties that did provide updated data (Job 3.1), we chose to focus our effort toward this objective on our study area near Carbondale. Based on our own ground-truthing, this area has seen a rapid increase in rural dwelling density (16% between 2001 and 2004) and we were able to bring a large data set of field-collected deer location data to bear (Job 3.4).

We modeled the similarity between habitat in our study area near Carbondale and the areas used most intensively by deer, and used this model to infer potential for deer-human interactions. Specifically, we used locations of GPS collared does and habitat variables including human dwellings within a GIS to (1) create a spatial map of deer use of the landscape, and (2) determine whether risk of human-deer contact was greater near human dwellings than at random sites on the landscape.

METHODS

Habitat Variable Calculation

Initially, 21 variables were considered for habitat modeling. We used the land cover map described in Job 3.4 (Storm 2005) to delineate cover types into the following 4 classes: grassland, forest, cropland, and oldfield. Land cover data were reclassified to a 10 x 10 m pixel resolution, which was similar to the average error of GPS locations. Habitat variables based on land cover (n = 18) within a 50 x 50 m moving window centered on grid cells were calculated using FRAGSTATS Version 3 (Table 5, McGarigal et al. 2002). Three additional variables considered for modeling were (1) number of dwellings within the moving window, (2) distance (m) from each grid cell centroid to its nearest human dwelling (see Job 3.4), and (3) distance from each grid cell centroid to its nearest road segment (Illinois Department of Natural Resources 1996).

We then used cluster analysis (PROC VARCLUS, SAS Institute 2000) to identify groups of variables that were highly correlated among themselves and as uncorrelated as possible with variables in other clusters. We chose an eigenvalue cutoff of 0.9 for cluster separation. The most representative variable of each cluster was chosen based on the $1\text{-}R^2$ ratio (SAS Institute 2000), resulting in the following 8 variables for further analysis: number of human dwellings in the moving window, distance to nearest road, Shannon's diversity index of the landscape, proportion of cropland cover, proportion of grassland cover, proportion of forest cover, coefficient of variation of forest cover patch area, and coefficient of variation of grassland patch area.

Modeling Deer Habitat Use

We used the Penrose distance statistic (Manly 1986, Nielsen and Woolf 2002) to model deer habitat use based on the similarity between the mean habitat vector (based on 8 habitat variables) calculated from 6,571 grid cells containing >1 GPS locations from 20 collared does and each cell on the study area (n = 134,263 cells). We calculated Penrose distance (P) of cell I (each cell on the study area) as

$$P_i = \Sigma^{p}_{k=1} (x_{ki} - \mu_{kj})^2 / pV_k$$

where p is the number of habitat variables evaluated, x_{ki} is the value of variable k in cell I, μ_{kj} is the mean value of variable k in cells containing GPS locations, and V_k is the variance of variable k among all cells on the study area (Manly 1986). This statistic is similar to the Mahalanobis distance statistic (Manly 1986, Clark et al. 1993, Corsi et al. 1999, Browning et al. 2005) and Euclidean distance-based approaches (Conner and Plowman 2001, Perkins and Conner 2004) used by several researchers for habitat analyses. We then compared mean Penrose distance values between cells with GPS locations and all cells on the study area.

We made all Penrose distance calculations in a spreadsheet and appended the output database to the grid coverage to create a GIS map of Penrose distance for the study area. For display purposes, classification of grid cells on the map according to Penrose distance values was based on natural breaks in the data as calculated in ArcView 3.3; this option grouped Penrose distance values into 5 categories that minimized variance within each category. To determine the influence of individual variables on Penrose distance, we correlated (Spearman rank correlation) values for each variable with Penrose distance. We then buffered (radius = 100 m) 318 human dwellings and the same number of random areas on the study area and calculated Penrose distance within buffered areas to determine whether deer were using locales near human dwellings more or less than the rest of the study area.

RESULTS

Mean (±SD throughout) Penrose distance values for cells with GPS locations and the entire study area were 1.57±1.03 and 1.67±1.21, respectively. Mean Penrose distance for areas near human dwellings and random areas were 1.93±1.60 and 1.66±1.23, respectively. Penrose distance was positively correlated with all variables except the proportion of grassland cover

(Table 6). Three variables were highly correlated with Penrose distance $r > 0.40$): coefficients of variation of grassland and forest patches, and number of dwellings.

Deer used forest edges most intensively throughout the study area (Fig. 4). Moderately used areas were mostly associated with forest cover. Areas of lower use were found near dwellings or agricultural cover, with poorest habitat associated with water or old-field areas. Roads did not appear to affect deer habitat use except when near dwellings. When dwellings were more clumped, deer use was generally less intensive in the surrounding area (Fig. 5). However, when dwellings were located linearly, such as along roads, human dwellings were surrounded by proportionately more high deer-use areas.

DISCUSSION

We used the Penrose distance statistic to create a model of habitat similarity between areas used intensively by deer and the entire study area. Other studies have used distance statistics to model habitat suitability (Clark et al. 1993, Corsi et al. 1999, Browning et al. 2005). The primary advantage this has over other multivariate techniques (e.g., logistic regression) is that there is no need to assume that used and unused habitats are differentiated without error. This is an important advantage because we were studying a sample of all does on the study area, and we know that several portions of the study were certainly inhabited by deer that were not collared. The Penrose distance model allowed us to determine those areas where deer habitat use was most intensive, even though we did not have animals collared throughout the entire study area.

Our analysis indicates that much of exurban Carbondale is similar to areas used most intensively by deer; indeed, Penrose distance of the study area was only 6% lower than that of the most-used areas. However, when comparing habitat similarity between areas of high human activity (i.e., dwellings) and random areas, Penrose distance was 14% lower at random locations than near dwellings. This indicates that deer habitat use was probably less intensive near dwellings than in the rest of the study area, and suggests some avoidance of dwellings. These findings are consistent with the positive correlation between dwelling density and Penrose distance, and with our other analyses based on home ranges and core areas (see Job 3.4, Storm 2005) that found that deer tend to avoid dwellings, especially during the fawning season. However, although humans are less likely to encounter deer near dwellings, some areas of high deer use were very close to dwellings (e.g., at forest edges). This was especially evident when houses were arranged linearly and well-spaced on the landscape. Deer also appeared to exhibit some minor avoidance of roads, but only in areas near dwellings or where forest cover was not the dominant cover type.

The coefficients of variation of grassland and forest patch size and number of dwellings were the 3 variables most highly correlated to Penrose distance, which demonstrated their importance in affecting habitat use intensity of deer. These variables were positively correlated with Penrose distance, such that high variation in patch size of grassland and forest patches and abundant dwellings were associated with less-used habitat. The reason for this influence of patch size variance on deer habitat use is unclear, especially given the relative lack of study of such variables and their influence on deer habitat use. It was somewhat surprising that proportion of forest cover and landscape cover type diversity were positively correlated with Penrose distance. However, given the high use of forest edge cover (Fig. 4), proportion of forest cover alone was likely less important to deer. Further, even though increased edge may be expected in areas of high cover type diversity, edge associated with cover types other than forest cover were probably less used by deer. Positive correlations of proportion of cropland and grass cover and distance to nearest road to Penrose distance follow established patterns habitat use for deer (Nixon et al. 1991), suggesting that these items are avoided or otherwise relatively poor habitat when compared to forest cover.

RESEARCH AND MANAGEMENT IMPLICATIONS

We used location data commonly collected in radiotelemetry studies in conjunction with remotely sensed land cover data to assess deer habitat use-intensity on an exurban area in southern Illinois. This model can be used by wildlife managers to better understand potential deer-human encounters and deer use of the landscape in several ways. First, the model is useful for predicting risk of humans contracting zoonotic diseases, and can be used to educate exurbanites on how to avoid deer or disease vectors. For example, on our study area, humans should primarily avoid forest edges to minimize contact with deer. Alternatively, wildlife managers may use such a model to target deer removal operations or prescribe areas for hunters to consider for traditional harvest management. Given the challenges facing deer management in exurbia, habitat-based models such as these may be a valuable tool wildlife managers can use to increase deer harvest efficiency.

Finally, our analysis indicates that although deer somewhat avoid areas of highest human activity, the spatial patterns of dwellings themselves may affect the likelihood of deer-human encounters. We found that in portions of the study area where houses were well-spaced and arranged linearly on the landscape (primarily due to road placement), deer use was generally greater in the surrounding area than areas where dwellings were more clumped. Therefore, as suggested for road placement in urban environments (Nielsen et al. 2003), planners may wish to consider the implications of dwelling placement and its influence on deer-human interactions when planning new housing developments in exurbia.

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Table 5. Variables considered for modeling habitat use of deer in southern Illinois, 2003-05. Variables were calculated using FRAGSTATS Version 3 (McGarigal et al. 2002) for 4 land cover classes and the landscape, resulting in 18 variables calculated. Class metrics were calculated for grassland, forest, cropland, and oldfield land cover classes.

Calculation	Variable (unit)
Area and patch metrics	
Class	Percentage of landscape (ha)
Class/landscape	Patch area coefficient of variation (%)
Class/landscape	Mean patch area (ha)
Edge metrics	
Class/landscape	Edge density (m/ha)
Shape metrics	
Class/landscape	Mean shape index
Diversity metrics	
Landscape	Shannon's diversity index
Isolation/proximity metrics	
Class/landscape	Euclidean nearest neighbor distance

Table 6. Spearman rank correlations of 8 habitat variables used for deer habitat modeling in southern Illinois and Penrose distance (PD). Variable units are defined in Table 5 or the text.

Variable	Correlation between study area and PD
Proportion of grassland cover	-0.177
Proportion of forest cover	0.134
Proportion of cropland cover	0.032
Distance to nearest road	0.208
Number of dwellings	0.534
Coefficient of variation of forest patches	0.675
Coefficient of variation of grassland patches	0.416
Shannon’s diversity index of the landscape	0.157

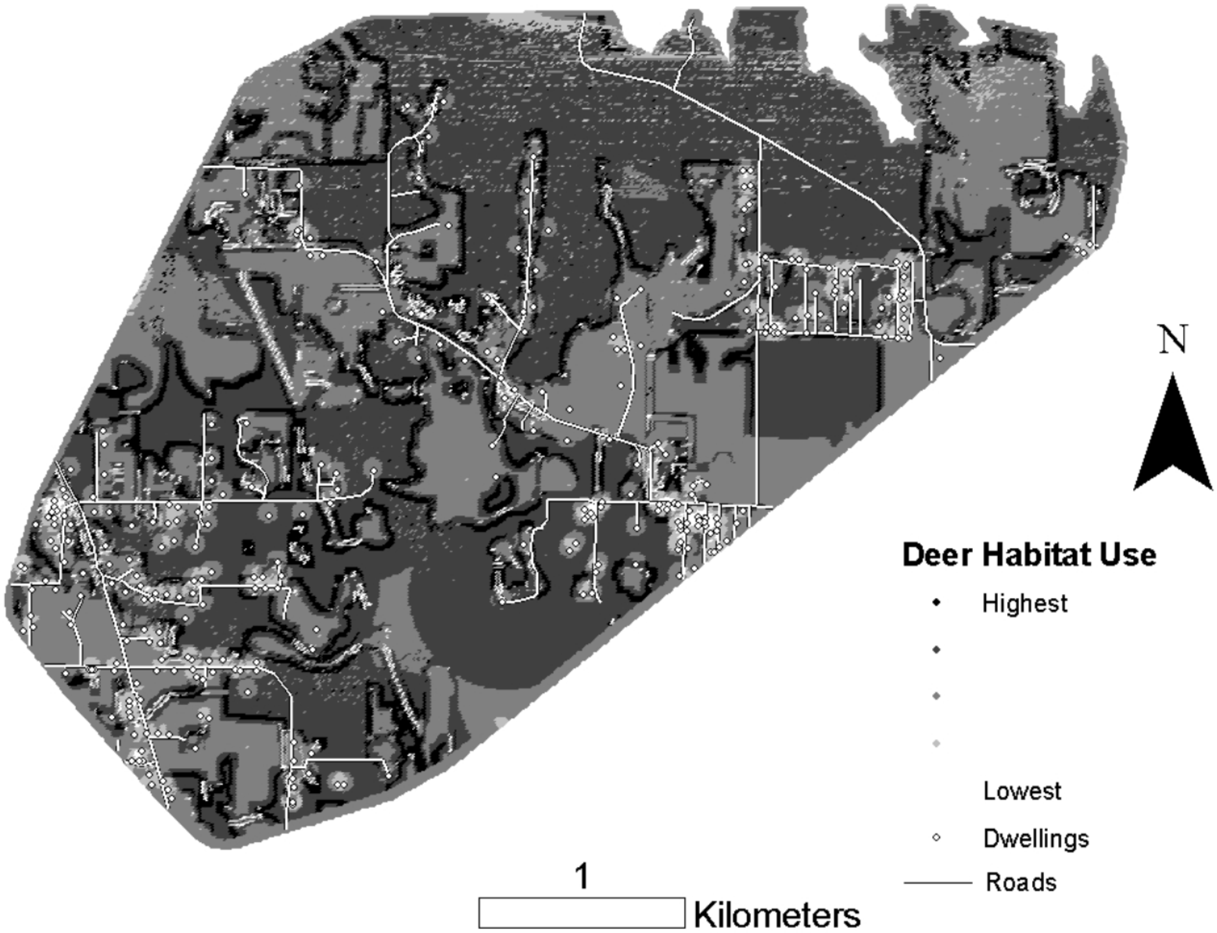

Figure 4. Female deer habitat use in exurban Carbondale, Illinois, derived from the Penrose distance statistic, 2003-05.

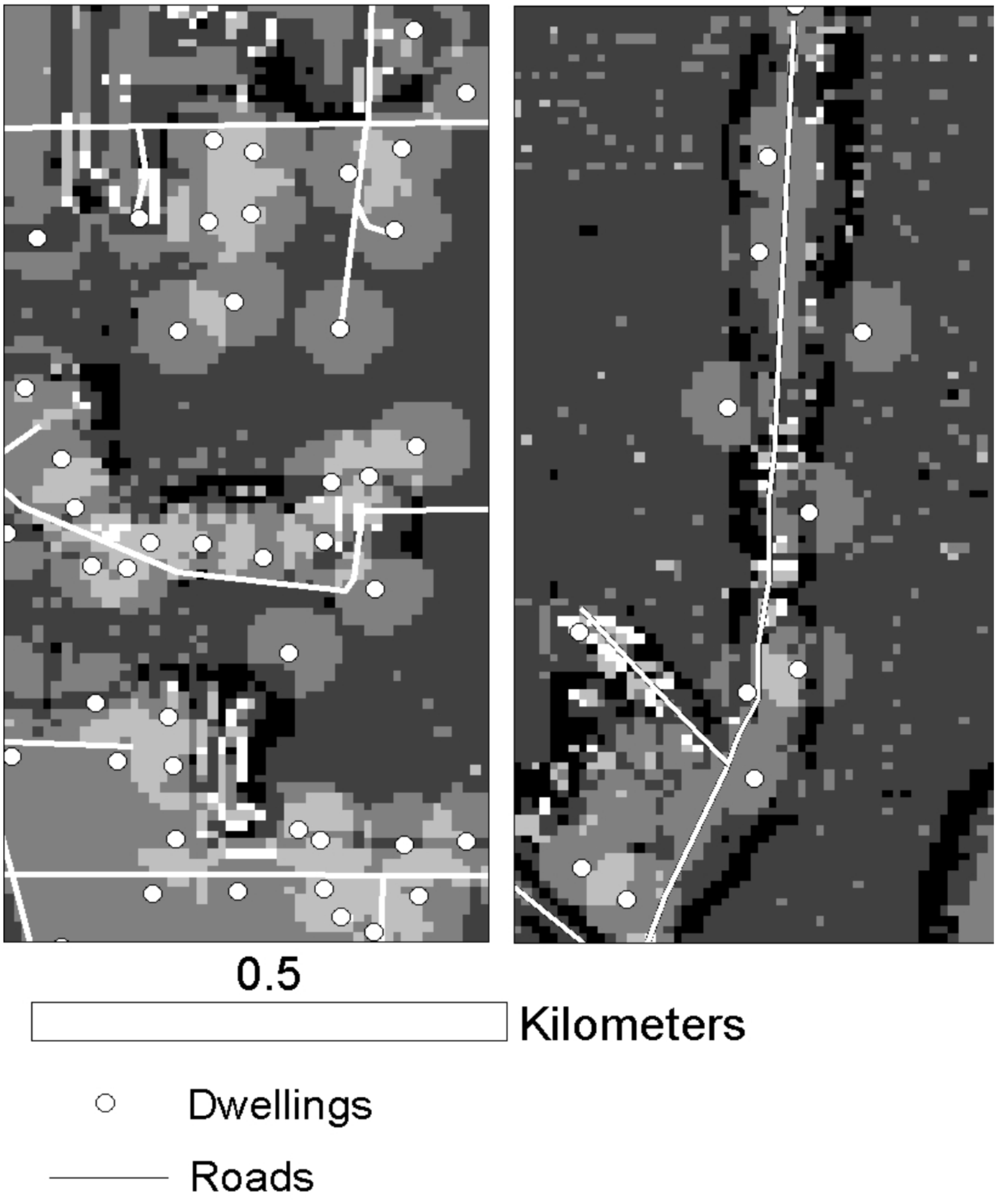

Figure 5. Comparison of female deer habitat use in exurban Carbondale, Illinois, derived from the Penrose distance statistic, 2003-05. The area depicted on the left contains a more clumped distribution of human dwellings and less-used deer habitat; the area on the right contains human dwellings located linearly along roads and associated with more-used deer habitat.

JOB 3.3: EFFECTS ON HUNTER DISTRIBUTION AND BEHAVIOR

Objective: Assess the effect of ex-urban development on hunter distribution in a select area of Illinois and develop models that can predict the impacts of rural development on hunter behavior statewide.

A Master's thesis (Storm 2005) is attached in lieu of a final report of the methods, results, and findings of this job.

LITERATURE CITED

Storm, D. J. 2005. White-tailed deer ecology and deer-human conflict in an exurban landscape. Thesis, Southern Illinois University, Carbondale, Illinois, USA.

JOB 3.4: EFFECTS ON DEER DISTRIBUTION AND POPULATIONS

Objective: Use data available on deer movements to investigate their use of the ex-urban landscape.

A Master's thesis (Storm 2005) is attached in lieu of a final report of the methods, results, and findings of this job.

LITERATURE CITED

Storm, D. J. 2005. White-tailed deer ecology and deer-human conflict in an exurban landscape. Thesis, Southern Illinois University, Carbondale, Illinois, USA.

JOB 3.5: ANALYSIS AND REPORT

Objective: Summarize information and propose management strategies to IDNR describing potential impacts of ex-urban development on herd density and hunter opportunity, success, and satisfaction.

Objectives were met through preparation of quarterly, annual, and this report. Also, periodic meetings were held with IDNR, Division of Wildlife Resources, Forest Wildlife Program staff to discuss findings and project progress.

STUDY 4. MODELING AND RISK ASSESSMENT OF CWD IN ILLINOIS

JOB 4.1: ESTIMATE CONTACT RATES

Objective: Develop estimates of contact rates based on multiple deer use of specific sites and use these rates to improve predictive models of CWD persistence and spread in Illinois.

A manuscript (Schauber et al. 2005) that details methods and findings for this job is attached. Following is an abstract of the manuscript.

Establishment and spread of infectious diseases are controlled by the frequency of contacts among hosts. Although transmission coefficients can be estimated from the relationship between disease prevalence and age or time, managers may wish to quantify or compare contact rates before a disease is established or while it is at very low prevalence. Our objective was to quantify direct and indirect contact rates among white-tailed deer (*Odocoileus virginianus*), and to compare these measures of contact rate with simpler measures of joint space use. We deployed global positioning system (GPS) collars on 23 deer near Carbondale, Illinois, 2002-2005. We used location data from the GPS collars to estimate pairwise rates of direct and indirect contact, based on a range of proximity criteria and pathogen half-lives, as well as volume of intersection (VI) of kernel utilization distributions. Direct contact rates increased with increasing VI, but were elevated in within-group pairs of deer above the level expected on the basis of their VI. Indirect contact rates exhibited a similar pattern, but the disparity between within- and between-group pairs decreased with increasing pathogen persistence. The ratio of within- to between-group direct contact rates increased from 6.3 to 10.9 as the proximity criterion defining a contact decreased from 100 to 10 m, but the within:between ratio of indirect contact rates was essentially constant (ca. 2) for half-lives between 7 and 180 d. These results indicate that simple measures of joint space use are insufficient indices of direct contact, because group membership can substantially increase contacts at a given level of

joint space use. Our findings also suggest that stable social groups could be treated as individuals in modeling spread of directly transmitted diseases in white-tailed deer populations. With indirect transmission, however, group membership had a much smaller influence. The use of GPS collars provides a framework for testing hypotheses about the form of contact networks among large mammals and comparing potential direct and indirect contact rates across gradients of ecological factors, such as population density or landscape configuration.

LITERATURE CITED

Schauber, E. M., D. J. Storm, and C. K. Nielsen. 2005. Quantifying direct and indirect contact rates among white-tailed deer. Journal of Wildlife Management (submitted).

JOB 4.2: ANALYSIS AND REPORT

<u>Objective</u>: Incorporate estimates of contact into CWD models to assess risk under various management options available to IDNR resource managers.

Objectives were met through preparation of quarterly, annual, and this report. Also, periodic meetings were held with IDNR, Division of Wildlife Resources, Forest Wildlife Program staff to discuss findings and project progress.