FINAL REPORT

W-87-R-17

Population Dynamics and Ecology of White-Tailed Deer in Illinois

Submitted by:

Cooperative Wildlife Research Laboratory, SIUC

Presented to:

Illinois Department of Natural Resources

August 1995

Prepared by:

Alan Woolf, Director
Coop. Wildlife Research Lab.
Southern Illinois University
Carbondale, IL 62901

Submitted by:

Alan Woolf, Director
Coop. Wildlife Research Lab.
Southern Illinois University
Carbondale, IL 62901

John L. Roseberry, Senior Scientist
Coop. Wildlife Research Lab.
Southern Illinois University
Carbondale, IL 62901

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

FINAL REPORT

STATE OF ILLINOIS

W-87-R-17

Project Period: 1 July 1992 through 30 June 1995

Study: Population dynamics and ecology of white-tailed deer in Illinois

Prepared by Alan Woolf and John L. Roseberry
Cooperative Wildlife Research Laboratory
Southern Illinois University at Carbondale

Need: Since modern firearm hunting of deer resumed in Illinois in 1957, county harvest quotas have been based on retrospective interpretation of the previous year's harvest data. Decisions are made in the absence of definitive knowledge of deer habitat distribution, quantity or quality. The productivity of Illinois deer coupled with a generally conservative approach to harvest management has permitted dramatic herd growth in most counties and regions. It is now apparent that more aggressive and innovative harvest strategies will be necessary to effectively manipulate the size and composition of these populations. To ensure that these new harvest regimes are both safe and effective, there will need to be more sophisticated and detailed analysis of harvest data as well as the ability to predict and evaluate the effects of proposed and implemented harvest strategies on size and composition of the deer herd and behavior and performance of hunters. At present, the Illinois deer management program lacks these capabilities.

In addition, more attention must be given to the amount, distribution, and quality of deer habitat on a county and

regional basis and how this habitat is spatially oriented in relation to road systems, human habitation, and sensitive agricultural areas. At the local level, habitat variables can often be measured directly. However, special problems arise in the acquisition, storage, analysis, and interpretation of habitat data on a county, regional, or statewide scale. Fortunately, recent advances in remote sensing, geographic information systems (GIS), and habitat modelling offer solutions to these problems. Progressive management of the Illinois deer herd requires that these capabilities be developed and utilized.

Objectives:

1. To assess the amount, distribution, and quality of white-tailed deer habitat in Illinois.

2. To relate spatial aspects of deer habitat to other important attributes such as hunter access, proximity to human habitation, and agricultural patterns.

3. To complete ongoing studies describing current natality rates, fawn recruitment, seasonal movements, and seasonal and annual mortality rates for previously marked deer in westcentral and northern Illinois.

4. To develop interactive, menu-driven, portable computer models and software packages to facilitate analysis of harvest data, predict effects of alternative harvest regimes, and help select appropriate strategies to achieve specific goals and objectives.

EXECUTIVE SUMMARY

This Study is a component of the Grant Agreement entitled **White-tailed Deer Project**. The project represents a cooperative effort between staff of the Illinois Natural History Survey (INHS), Center for Wildlife Ecology and the Cooperative Wildlife Research Laboratory at Southern Illinois University at Carbondale (SIUC). One study objective (Objective 3 above) was the sole responsibility of INHS staff and the results of that task (Job B, Deer Ecology and Life History in Westcentral and Northern Illinois) will be reported separately by the INHS.

Job A (Habitat Inventory, Classification, and Analysis) of this study was designed as a fully collaborative effort. We planned to develop the classification from statewide coverage of Landsat TM scenes selected by INHS staff. Also, we assumed that INHS staff with expertise in classification of Landsat TM scenes would be active participants and would lend technical support to this task. Indeed, we anticipated that a complete classification would be available by the end of Segment 15 so we could focus resources on other tasks planned under Job A. Further, because the land use/land cover classification of the entire state also was an important need of W-106-R-6 (Cooperative Upland Studies), there was shared responsibility for the task between both projects.

Because of unanticipated staff departures it became clear that the INHS would not participate in developing a statewide classification, and SIUC staff would have to assume sole

responsibility. Following consultations with Illinois Department of Natural Resources (IDNR) Program Managers, we made completion of a statewide classification the priority objective of Job A and used all available resources to complete that task. The scope and complexity of producing a land cover classification for Illinois using PC-based software was further complicated by limitations of the Landsat TM data available for the project thru the INHS. This added problem was not resolved until Segment 17 when SIUC's Morris Library acquired Landsat scenes of most portions of Illinois that were better suited for land cover classification than the original scenes we had to work with.

As a result of these unanticipated complications, all planned objectives of Job A were not accomplished. Job A objectives 1 and 2 (the primary objectives agreed to by IDNR Program Managers and project Principal Investigators) were completed and there is now a statewide land cover classification of Illinois available. Job A objective 3 was to be addressed as a portion of the narrative for Job B reported by the INHS. The lack of data (e.g. the statewide classification) precluded addressing objectives 4 and 5.

All objectives of Job C were completed. In fact, we developed 2 software packages; 1 to archive and analyze deer harvest data, and another that can access and analyze harvest data, but also can model and/or simulate herd performance. The latter software is especially useful for proactive planning and herd management.

In conclusion, accomplishments during this Grant Agreement period have been substantial. Although not all objectives of Job A were completed, prioritization of resources and effort allowed the development of a statewide land cover classification. This was a major accomplishment that will serve the information and management needs of multiple programs within the Illinois Department of Natural Resources.

This project final report describes what was accomplished and methods used to develop the products described. However, the results of this project are, in fact, products not included in the report text. The classified imagery is one major product. It is stored on optical disks at the Cooperative Wildlife Research Laboratory as individual county files. The Laboratory will use the imagery to support IDNR information needs during subsequent project segments. The other major products are 2 software programs to serve information and management needs of the IDNR Forest Wildlife Program. Two user's manuals describing the software and a programmer's guide are appended to this report.

JOB A. <u>Habitat Inventory, Classification, and Analysis</u>

<u>Objectives</u>: (1) To investigate alternative techniques for classifying white-tailed deer habitat from remote sensing data; (2) to use these techniques and data sources to inventory deer habitat in Illinois; (3) to describe the

habitat characteristics of sites selected by dispersing deer and to compare these characteristics with the habitats available within the boundaries of known dispersals from marking sites in northern, westcentral, and eastcentral Illinois; (4) to develop HSI models for the purpose of assessing the relative quality of deer habitat using digital land use classifications from remotely sensed data; and (5) to integrate information relating to spatial distribution of habitat with other pertinent attributes relating to hunter access, human habitat, and agricultural patterns.

INTRODUCTION

The powerful tools of remote sensing and geographical information system (GIS) software afford resource managers opportunity to develop large data bases that can provide the quantity and quality of information needed for resource management at landscape scales. A land use/land cover classification is a prerequisite foundation upon which resource managers can build GIS data layers that describe location and relative quality of habitat and its spatial relationships to potentially sensitive human developments and agricultural areas.

Our investigations of alternative techniques for classifying white-tailed deer habitat from remote sensing data quickly revealed that only satellite imagery afforded adequate spatial coverage. Landsat 5 TM scenes with 30 m pixel resolution offered an optimum scale (extent and grain) for our proposed

classification. The fortuitous availability of statewide Landsat 5 coverage for project use made that the imagery of choice. The number of classes that could be identified in the processed image was considered, and we concluded that a classification consisting of 6 classes would be appropriate. Generally, the complexity of our classification is similar to that described as Level 1 by Anderson et al. (1976). Finally, we considered the implications of accuracy of the final classification and set a goal of ≥90% overall classification accuracy.

METHODS

Data Sets

Landsat 5 TM Data.--Initially, satellite imagery purchased by the Illinois Natural History Survey was used for this project. This satellite coverage of Illinois consists of 9 full and 2 quarter scenes that are geographically referenced, terrain corrected and mosaicable. The INHS scene dates range from May 1988 to June 1991 (Fig. 1). Data were acquired in TM Fast format on 8 mm Exabyte tapes from INHS. Many of these scenes were difficult to classify which led to a large amount of confusion between several land use classes.

For these confused areas, we used additional satellite imagery owned by the Cooperative Wildlife Research Laboratory (CWRL), and SIUC's Morris Library. These additional scenes range in date from 10 September 1992 to 3 October 1993. Each county classified, the satellite imagery used, and the scene dates are listed in Table 1.

TIGER/Line(TM) Census Files.--TIGER (Topographically Integrated Geographic Encoding and Reference System) is a digital map base used to support Census Bureau programs. The 1990 Census TIGER/Line files contain digital data for features such as streets, rivers and streams, railroads, and political boundaries. The TIGER data set for all Illinois counties was acquired from SIUC's Morris Library.

Aerial Photography.--National Aerial Photography Program (NAPP) 1988, black and white, 1:40,000 scale positive prints available for all of Illinois was the main source for verification of land use classes. A complete set of photographs was made available for the project by Morris Library at SIUC. Color infrared prints from the CWRL map library were used to verify classifications in some areas. Sets of NAPP black and white contact print enlargements (3x) that covered bobwhite and pheasant call count routes in 90 counties were provided by the IDNR. These photos, with accompanying ground truth information, were used for accuracy assessments of each county's satellite classification.

USGS Topographical Maps.--U.S. Geological Survey 7.5-minute quadrangle maps were obtained from both SIUC's Morris Library and the CWRL map library. The most recent copies of these maps were used to identify and digitize orchards in counties that had significant amounts of this land use type. In some cases they were also used to verify other land use types.

Classification Scheme

Six land cover types were identified (crop, woods, grass, water, developed, and orchards) generally similar to the complexity of a classification described as Level 1 by Anderson et al. (1976). Crops included all cultivated acreage in row crops and small grains, as well as miscellaneous cultivated crops. Woods included coniferous forest, deciduous forest, and late old fields. Grass included hay, pasture, fallow fields, Conservation Reserve Program (CRP) fields, field edges, lawns, roadsides, and any other herbaceous cover not considered crop. Water included lakes, rivers, ponds, and other areas with permanent water. Developed areas were defined using TIGER data. Orchards were defined from topographic maps.

Preprocessing

Preprocessing Landsat TM data consisted of importing raw files into Map and Image Processing System (MIPS, MicroImages Inc., Lincoln, NE) software (Miller et al. 1989). Polygons defining broad natural divisions adapted from Schwegman (1973) were digitized over satellite imagery and plotted to binary rasters coregistered to the original scene. These binary rasters were used to extract natural divisions within each scene to limit spectral variability for automatic classification. Cumulus clouds and their shadows were delineated with polygons using the satellite images as a reference. The polygons were plotted to

coregistered binary rasters which were used to remove them from the classification to also limit spectral variability.

A principal components analysis was performed on bands 1, 2, and 3 for each natural division and the first principal component (PC1) was saved. A Normalized Difference Vegetation Index (NDVI) also was calculated (Lillesand and Kiefer 1987). Spectral Bands 4, 5, 7, PC1 and NDVI were input in MIPS to an ISOCLASS algorithm which generated approximately 200 ISOCLASS output classes.

TIGER data were processed to provide coregistered maps of developed areas and primary and secondary highways which were combined with the isoclassification of the satellite data. Developed areas were delineated using neighborhood roads extracted from TIGER files and plotted to a false color composite image of each scene. A vector of the Illinois state boundary was edited over this image and polygons were drawn around clusters of neighborhood roads. These polygons, which represented developed areas, were cross referenced with hard copy maps of Illinois and defined the "developed" habitat class. Visible quarries and other development areas were also identified in this fashion and put into the developed class.

Primary and secondary highways were extracted from TIGER files for each county within a scene and mosaicked. Primary highways were plotted to a coregistered binary raster and given a width of 2 pixels and digital value of 1. Secondary roads were plotted to the same binary raster, given the same digital value, but with a width of 1 pixel. The polygons representing developed

areas were also plotted using this binary raster with a value of 1 on the inside. This binary raster, representing highways and developed areas, was combined with the results of the isoclassification so that developed areas and highways had a digital value of 205 and a distinct color.

Orchards could not be classified using the satellite imagery, but they were identified from USGS 7.5-minute quadrangle maps. The 1992 agricultural census (U.S. Dep. of Commerce 1994) revealed that 23 counties that had more than 48 ha of orchards accounted for 73% of Illinois orchards. Orchards were manually digitized using the maps for these 23 counties (Appendix A) and combined with their respective county classification.

Classification Procedures

After the initial automatic classifications were run and the ancillary TIGER data added, results (approximately 200 isoclasses) were grouped into meaningful information classes or land use types. We tested 2 methods for lumping classes. The first used 1-mile^2 (2.59-km^2) sample boxes systematically placed over the satellite scene at 10-mile (15.1-km) intervals for ground truth data acquisition. Sample boxes then were delineated on acetate overlays for NAPP black and white positive prints. The land-use classes interpreted within each sample box were drawn onto the acetate overlay.

The land use for each sample box was then digitized to a georegistered raster using the raw satellite image as a reference.

These data were used to lump the isoclasses into information classes based on the correlation of the ISOCLASS values to the digital ground truth data within each sample box. This method proved to be time prohibitive for the large area to be classified and was discontinued.

Alternatively, we examined individual ISOCLASS values for a particular scene and natural division, and used photo verification to determine the most prevalent land use class associated with each ISOCLASS value. Color for each ISOCLASS value was assigned to emulate a false color image. Each ISOCLASS was then flashed and the most prevalent land use associated with that ISOCLASS value was determined. Information about the amount and type of confusion associated with each ISOCLASS value was recorded. After extensive photo verification, we found that many of the resulting ISOCLASS values were confused between 2 or more land use classes.

Each natural division of each scene was reviewed and only ISOCLASSES that showed little or no confusion were retained. A binary raster was created indicating the location of all the confused ISOCLASSES for each scene and natural division. These areas were then re-classified using a maximum likelihood classifier to calculate the statistical probability of a given pixel belonging to a particular land use class (Lillesand and Kiefer 1987). The results of this classifier were combined with the unconfused results from the isoclassification and evaluated. As an initial accuracy assessment, the percent of land cover

types for each extracted county was compared to existing estimates of land use. If these estimates varied from our classification by >10% the county was evaluated using aerial photos.

Even after reclassifying these scenes, acceptable accuracies were not attained for many counties. These counties were then individually re-classified, using only the maximum likelihood classifier. Counties that were not yet processed also were individually classified using the maximum likelihood classifier. Different satellite imagery, owned by the CWRL and SIUC's Morris Library, was then used for counties that still proved difficult to classify accurately. The majority of this imagery were autumn scenes taken in October that were much easier to classify.

After each county was extracted and spectrally classified, a contextual classifier was used to improve the classification. The contextual classifier was a series of FORTRAN programs that sequentially manipulated the classified output for each county. The first program detected single isolated pixels of any class and replaced them with the surrounding majority land use class. The program also removed linear crop features by replacing 1-pixel wide strips of crop, that had grass pixels on opposite sides with grass. The second program used output from the first to determine size of contiguous crop patches. This program created an output raster with pixel values representing the size of their respective patch. The next program replaced crop patches <13 pixels with the surrounding majority land-use class.

The final program replaced any new single pixels created by the previous programs with the surrounding majority land-use class.

Accuracy Assessment

The classification accuracy of the completed counties was assessed using land cover information collected along 0.5-mile (0.8-km) wide and 20-mile (32.25-km) long quail and pheasant call-count routes. The land cover along these routes was identified and mapped on aerial photos by IDNR biologists via field inspections during the summers of 1990 and 1991. Conservation Reserve Program (CRP) enrollment for each county was also recorded along each route.

Representative samples >3 ha of each land cover type were selected on the aerial photographs for each call count route. Between 50 and 90 samples per county were used depending upon the homogeneity of the landscape and meander of the route. These samples then were located on the classified county image and their land use types were compared. There were 6 pairs of counties (Gallatin-Hardin, Marshall-Putnam, Jasper-Clay, Stephenson-Winnebago, Carroll-Jo Daviess, and McDonough-Fulton) that had a single route extending across both counties. In these cases, the same set of sample points were used for both county accuracy assessments. An error matrix was constructed for each call count route and used to compute errors of omission and commission, overall accuracy, and the Kappa statistic (Congalton 1991). Accuracy assessment data sampled for each county also

were pooled, without the duplicate sample points mentioned above, for statewide estimates.

RESULTS AND DISCUSSION

We classified 99 of 102 Illinois counties (Cook, Du Page, and Lake counties were not classified). The quality (accuracy) of each county classification varied with the quality and acquisition date of the satellite imagery used. Scenes originally acquired from INHS ranged in date from May 26, 1988 to June 10, 1991 and spanned from early spring to summer. The scenes acquired from SIUC's Morris Library ranged only from September 10, 1992 to October 12, 1992 and were much easier to accurately classify.

Overall classification accuracy ranged from 77% for Kendall County to 98% for Macon County and averaged 91.8% over all the counties (Table 2). The Kappa value ranged from 0.58 for Kendall County to 0.98 for Peoria County and averaged 0.88 over all counties. The woods and water classes were the most accurately defined; errors of omission and commission for woods averaged 2.1 and 1.5%, respectively. The errors of omission and commission for water averaged 3.8 and 0.1%, respectively. Average error estimates for crop and grass were notably higher. The errors of omission and commission for crop averaged 3.7 and 17.5% respectively, whereas omission and commission errors for grass averaged 23.6 and 6.4%, respectively. Accuracy assessment data sampled for each county also were pooled for statewide estimates

(Table 3). These estimates were very similar to the average county accuracy assessments. Overall statewide accuracy was 92% with a Kappa value of 0.88. Once again, woods and water were the most accurate with errors of omission and commission <3.0%. The errors of omission and commission for crop were 3.5 and 16.3%, respectively. Errors of omission and commission for grass were 23.4 and 6.0%, respectively.

Our statewide classification compared well with other land use classifications using Landsat 5 TM data. Sader et al. (1991) reported a 70% overall classification accuracy (93% for woods) for an area of Costa Rica. Airola and Vogel (1988) classified TM data for New Jersey and reported an overall accuracy of 91.8% (94.1% for woods and 82.4% for agriculture). Moore and Bauer (1990) reported an overall accuracy of 67% for their classification of TM data in northern Minnesota. Because our classification accuracy varied by county and by land use type, we have provided detailed estimates of accuracy for each county we reviewed (Appendix B).

LITERATURE CITED

Airola, T. M., and J. Vogel. 1988. Use of thematic mapper digital data for updating the New Jersey land cover component of the 1987 National Resources Inventory. J. Soil & Water Conserv. 43:425-428.

Anderson, J. R., E. E. Hardy, J. T. Roach and R. E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geologic Survey Prof. Paper 964. 26pp.

Congalton, R. G. 1991. A review of assessing the accuracy of classifications of remotely sensed data. Remote Sensing Environ. 37:35-46.

Lillesand, T. M., and R. W. Kiefer 1987. Remote sensing and image interpretation. John Wiley & Sons, New York. 721pp.

Miller, L. D., M. Unverferth, K. Ghormley, and M. P. Skrdla. 1989. A guide to MIPS. MicroImages, Inc., Lincoln, Neb. 97pp.

Moore, M. M., and M. E. Bauer. 1990. Classification of forest vegetation in north-central Minnesota using Landsat multispectral scanner and thematic mapper data. For. Sci. 36:330-342.

Sader, S. A., G. V. Powell and J. H. Rappole. 1991. Migratory bird habitat monitoring through remote sensing. Int. J. Remote Sensing. 12:363-372.

Schwegman, J. E. 1973. Comprehensive plan for the Illinois nature preserves system part 2: the natural divisions of Illinois. Ill. Nature Preserves Comm., Springfield. 32pp.

U.S. Dep. of Commerce 1994. 1992 census of agriculture, volume 1 geographic area series, part 13, Illinois state and county data. U.S. Gov. Printing Office, Washington, DC. 541pp.

Table 1. Data on Landsat 5 TM scenes used to classify each Illinois county.

County	Scene1[a]	Scene2	Source	Date1	Date2
Adams	P24R32		INHS	06/24/90	
Alexander	P23R34		MORRIS	10/12/92	
Bond	P23R33		INHS	05/26/88	
Boone	P23R31	P24R31	INHS	06/30/89	06/24/90
Brown	P24R32		INHS	06/24/90	
Bureau	P24R31		INHS	06/24/90	
Calhoun	P24R33		INHS	04/24/91	
Carroll	P24R31		INHS	06/24/90	
Cass	P24R32		INHS	06/24/90	
Champaign	P23R32		INHS	05/26/88	
Christian	P23R33	P23R32	INHS	05/26/88	05/26/88
Clark	P22R33		INHS	06/10/90	
Clay	P23R33	P22R33	INHS	05/26/88	06/10/90
Clinton	P23R33		INHS	05/26/88	
Coles	P22R33		INHS	06/10/90	
Cook	P23R31		MORRIS	09/10/92	
Crawford	P22R33		INHS	06/10/90	
Cumberland	P22R33		INHS	06/10/90	
De Kalb	P23R31		MORRIS	09/10/92	
De Witt	P23R32		INHS	05/26/88	
Douglas	P23R32		INHS	05/26/88	
Du Page	P23R31		MORRIS	09/10/92	
Edgar	P22R32	P22R33	INHS	06/10/90	06/10/90
Edwards	P22R33		INHS	06/10/90	
Effingham	P23R33		INHS	05/26/88	
Fayette	P23R33		INHS	05/26/88	
Ford	P23R32		INHS	05/26/88	
Franklin	P23R34		MORRIS	10/12/92	
Fulton	P24R32		INHS	06/24/90	
Gallatin	P22R34		INHS	06/10/90	
Greene	P24R33		INHS	04/24/91	
Grundy	P23R31		INHS	06/30/89	
Hamilton	P22R34	P22R33	INHS	06/10/90	06/10/90
Hancock	P24R32		INHS	06/24/90	
Hardin	P22R34		INHS	06/10/90	
Henderson	P24R32		INHS	06/24/90	
Henry	P24R31		MORRIS	10/03/92	
Iroquois	P23R32	P23R31	MORRIS	10/12/92	09/10/92
Jackson	P23R34		MORRIS	10/12/92	
Jasper	P22R33		INHS	06/10/90	
Jefferson	P23R33		INHS	05/26/88	
Jersey	P24R33		INHS	04/24/91	
Jo Daviess	P24R31		INHS	06/24/90	
Johnson	P23R34		MORRIS	10/12/92	

Table 1. Continued.

County	Scene1[a]	Scene2	Source	Date1	Date2
Kane	P23R31		MORRIS	09/10/92	
Kankakee	P23R31		MORRIS	09/10/92	
Kendall	P23R31		MORRIS	09/10/92	
Knox	P24R32		INHS	06/24/90	
La Salle	P23R31		INHS	06/30/89	
Lake	P23R31		MORRIS	09/10/92	
Lawrence	P22R33		INHS	06/10/90	
Lee	P24R31		INHS	06/24/90	
Livingston	P23R32		INHS	05/26/88	
Logan	P23R32		INHS	05/26/88	
Macon	P23R32		INHS	05/26/88	
Macoupin	P23R33		INHS	05/26/88	
Madison	P23R33		INHS	05/26/89	
Marion	P23R33		INHS	05/26/88	
Marshall	P24R31		MORRIS	10/03/92	
Mason	P24R32		MORRIS	10/03/92	
Massac	P23R34		MORRIS	10/12/92	
McDonough	P24R32		INHS	06/24/90	
McHenry	P23R31		MORRIS	09/10/92	
McLean	P23R32		INHS	05/26/88	
Menard	P24R32		INHS	06/24/90	
Mercer	P24R31	P24R32	MORRIS	10/03/92	10/03/92
Monroe	P24R33		INHS	04/24/91	
Montgomery	P23R33		INHS	05/26/88	
Morgan	P24R32		INHS	06/24/90	
Moultrie	P23R32		INHS	05/26/88	
Ogle	P24R31		INHS	06/24/90	
Peoria	P24R32		INHS	06/24/90	
Perry	P23R34		MORRIS	10/12/92	
Piatt	P23R32		INHS	05/26/88	
Pike	P24R33	P24R32	INHS	04/24/91	06/24/90
Pope	P23R34		MORRIS	10/12/92	
Pulaski	P23R34		MORRIS	10/12/92	
Putnam	P24R31		MORRIS	10/03/92	
Randolph	P23R34		MORRIS	10/12/92	
Richland	P22R33		INHS	06/10/90	
Rock Island	P24R31		MORRIS	10/03/92	
Saline	P22R34		INHS	06/10/90	
Sangamon	P23R33		INHS	05/26/88	
Schuyler	P24R32		MORRIS	10/03/92	
Scott	P24R32		INHS	06/24/90	
Shelby	P23R33		INHS	05/26/88	
St. Clair	P23R34		MORRIS	10/12/92	
Stark	P24R31		INHS	06/24/90	
Stephenson	P24R31		INHS	06/24/90	

Table 1. Continued.

County	Scene1[a]	Scene2	Source	Date1	Date2
Tazewell	P24R32	P23R32	INHS	06/24/90	05/26/88
Union	P23R34		MORRIS	10/12/92	
Vermilion	P22R32		INHS	06/10/90	
Wabash	P22R33		INHS	06/10/90	
Warren	P24R32		INHS	06/24/90	
Washington	P23R33		INHS	05/26/88	
Wayne	P22R33		INHS	06/10/90	
White	P22R33	P23R34	INHS	06/10/90	06/10/90
Whiteside	P24R31		INHS	06/24/90	
Will	P23R31		MORRIS	09/10/92	
Williamson	P23R34		INHS	04/17/91	
Winnebago	P24R31	P23R31	INHS	06/24/90	06/30/89
Woodford	P23R32		MORRIS	10/12/92	

[a]P=Path, R=Row.

Table 2. Summary of land use classification accuracy assessment and percent errors of omission (O) and commission (C) for Illinois counties classified from Landsat 5 TM satellite data.

County	Crop		Grass		Woods		Water		Accuracy*	
	O	C	O	C	O	C	O	C	Overall (%)	Kappa
Adams	16	28	25	18	0	0	7	0	86	0.81
Alexander	no accuracy assessment									
Bond	no accuracy assessment									
Boone	0	10	4	0	0	0	22	0	97	0.95
Brown	8	19	22	9	0	0	0	10	92	0.88
Bureau	3	21	31	0	0	6	0	0	90	0.85
Calhoun	no accuracy assessment									
Carroll	6	6	5	10	6	0	0	0	95	0.93
Cass	3	16	26	5	0	0	0	0	92	0.89
Champaign	0	11	18	0	8	0	0	0	95	0.92
Christian	7	7	15	15	0	0	0	0	93	0.90
Clark	0	33	44	6	4	4	11	0	87	0.81
Clay	4	25	40	13	0	0	14	0	87	0.81
Clinton	8	23	35	10	0	7	0	0	87	0.82
Coles	0	21	38	0	0	0	0	0	91	0.87
Cook	no accuracy assessment									
Crawford	14	14	30	20	0	5	0	0	90	0.86
Cumberland	0	7	12	0	0	0	0	0	97	0.96
De Kalb	0	6	17	0	-	-	0	0	96	0.92
De Witt	0	24	24	6	38	0	0	0	87	0.80
Douglas	30	27	56	6	0	0	0	0	85	0.76
Du Page	no accuracy assessment									
Edgar	3	3	4	9	12	0	0	0	96	0.93
Edwards	4	17	14	5	0	0	8	0	94	0.91
Effingham	4	30	35	12	7	0	12	0	86	0.80
Fayette	0	23	25	0	0	0	0	0	93	0.90
Ford	0	5	10	0	0	0	0	0	97	0.96
Franklin	7	11	12	12	5	0	0	0	93	0.90
Fulton	0	38	45	15	10	5	17	0	83	0.76
Gallatin	0	19	14	0	0	0	0	0	95	0.93

Table 1. Continued.

County	Crop		Grass		Woods		Water		Accuracy*	
	O	C	O	C	O	C	O	C	Overall (%)	Kappa
Greene	no accuracy assessment									
Grundy	7	3	10	20	0	0	0	0	95	0.92
Hamilton	11	0	0	8	0	0	0	0	97	0.96
Hancock	0	6	4	13	0	0	75	0	92	0.88
Hardin	0	19	14	0	0	0	0	0	95	0.93
Henderson	0	38	53	0	0	6	33	0	84	0.76
Henry	0	5	12	0	0	0	0	0	97	0.96
Iroquois	3	6	18	0	0	11	0	0	95	0.91
Jackson	0	18	19	0	0	0	0	0	95	0.93
Jasper	4	25	40	13	0	0	14	0	87	0.81
Jefferson	4	39	43	5	0	0	0	0	87	0.82
Jersey	0	10	18	0	0	0	0	0	96	0.94
Jo Daviess	6	6	5	10	6	0	0	0	95	0.93
Johnson	12	25	9	4	0	0	0	0	95	0.93
Kane	0	12	20	0	0	0	0	0	95	0.93
Kankakee	0	12	25	0	-	-	0	0	93	0.86
Kendall	3	39	86	0	11	11	0	0	77	0.58
Knox	no accuracy assessment									
Lake	no accuracy assessment									
La Salle	0	31	36	0	0	0	0	0	88	0.83
Lawrence	0	18	17	6	5	10	50	0	89	0.85
Lee	0	12	27	0	0	0	0	0	95	0.93
Livingston	0	13	27	0	0	0	0	0	93	0.88
Logan	0	9	12	0	0	0	12	0	96	0.94
Macon	0	4	10	0	0	0	0	0	98	0.97
Macoupin	4	12	15	5	0	0	0	0	94	0.92
Madison	9	9	19	25	7	0	0	0	91	0.87
Marion	4	27	33	6	0	0	0	0	90	0.87
Marshall	0	6	20	0	0	0	0	0	96	0.94
Mason	3	45	74	5	0	6	8	0	80	0.71
Massac	0	17	14	0	0	0	0	0	96	0.94
McDonough	0	38	45	15	10	5	17	0	83	0.76

[illegible] continued.

County	Crop		Grass		Woods		Water		Accuracy[a]	
	O	C	O	C	O	C	O	C	Overall (%)	Kappa
McHenry	no accuracy assessment									
McLean	no accuracy assessment									
Menard	no accuracy assessment									
Mercer	no accuracy assessment									
Monroe	5	33	37	5	0	0	0	0	88	0.84
Montgomery	6	24	31	15	6	0	0	0	89	0.85
Morgan	4	14	24	6	0	0	0	0	93	0.91
Moultrie	no accuracy assessment									
Ogle	0	17	17	4	7	13	22	0	90	0.86
Peoria	0	4	9	0	0	0	0	0	98	0.98
Perry	4	12	17	6	0	0	0	0	95	0.93
Piatt	0	7	9	0	0	0	0	0	97	0.96
Pike	4	8	10	5	0	0	0	0	96	0.95
Pope	12	25	9	4	0	0	0	0	95	0.93
Pulaski	4	4	6	6	6	6	0	0	96	0.94
Putnam	0	6	20	0	0	0	0	0	96	0.94
Randolph	4	8	11	1	4	0	0	0	95	0.93
Richland	4	20	31	5	0	0	0	0	92	0.89
Rock Island	3	10	14	5	0	0	0	0	95	0.92
Saline	0	50	52	0	0	0	0	7	85	0.80
Sangamon	2	2	6	18	11	0	0	0	96	0.93
Schuyler	18	7	15	38	0	0	0	0	90	0.87
Scott	8	4	5	10	0	0	0	0	96	0.94
Shelby	0	25	32	10	10	0	0	0	88	0.84
Stark	no accuracy assessment									
St. Clair	0	12	19	0	0	0	0	0	95	0.93
Stephenson	3	31	40	0	0	4	0	0	88	0.82
Tazewell	0	9	15	0	0	0	0	0	96	0.93
Union	16	10	15	23	0	0	0	0	92	0.89
Vermilion	0	6	12	0	0	0	0	0	97	0.95
Wabash	0	19	31	0	0	0	0	0	93	0.90
Warren	0	37	38	0	7	0	0	0	87	0.81

Table 1 continued.

County	Crop		Grass		Woods		Water		Accuracy*	
	O	C	O	C	O	C	O	C	Overall(%)	Kappa
Washington	4	28	30	5	0	0	8	0	90	0.86
Wayne	14	46	57	10	0	15	0	0	81	0.75
White	12	29	42	17	0	0	0	0	85	0.79
Whiteside	4	19	26	10	5	0	0	0	89	0.84
Will	12	0	0	30	0	0	0	0	94	0.91
Williamson	14	27	24	12	0	0	0	0	89	0.85
Winnebago	3	31	40	0	0	4	0	0	88	0.82
Woodford	2	2	8	0	0	11	0	0	97	0.95

*The accuracy assessments are as follows:

Overall accuracy = the total number of fields correctly classified, divided by the total number of fields sampled, multiplied by 100.

Kappa statistic = A normalized accuracy assessment which accounts for fields correctly classified by chance (Congalton 1991).

Table 3. Accuracy assessment and error estimate[a] samples pooled for an overall statewide estimate of accuracy.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Crop	2134	65	12	0	2211	3.5	16.3	96.5
Grass	341	1144	7	1	1493	23.4	0	76.6
Woods	9	17	1331	0	1357	1.9	1.7	98.1
Water	10	7	4	674	695	3.0	0.1	97.0
Sum	2494	1233	1354	675	5756			

Overall Accuracy: 92% Kappa: 0.88

[a]Calculated according to Congalton 1991.
[b]Ground truth data from Illinois Department of Natural Resources quail and pheasant call count routes.

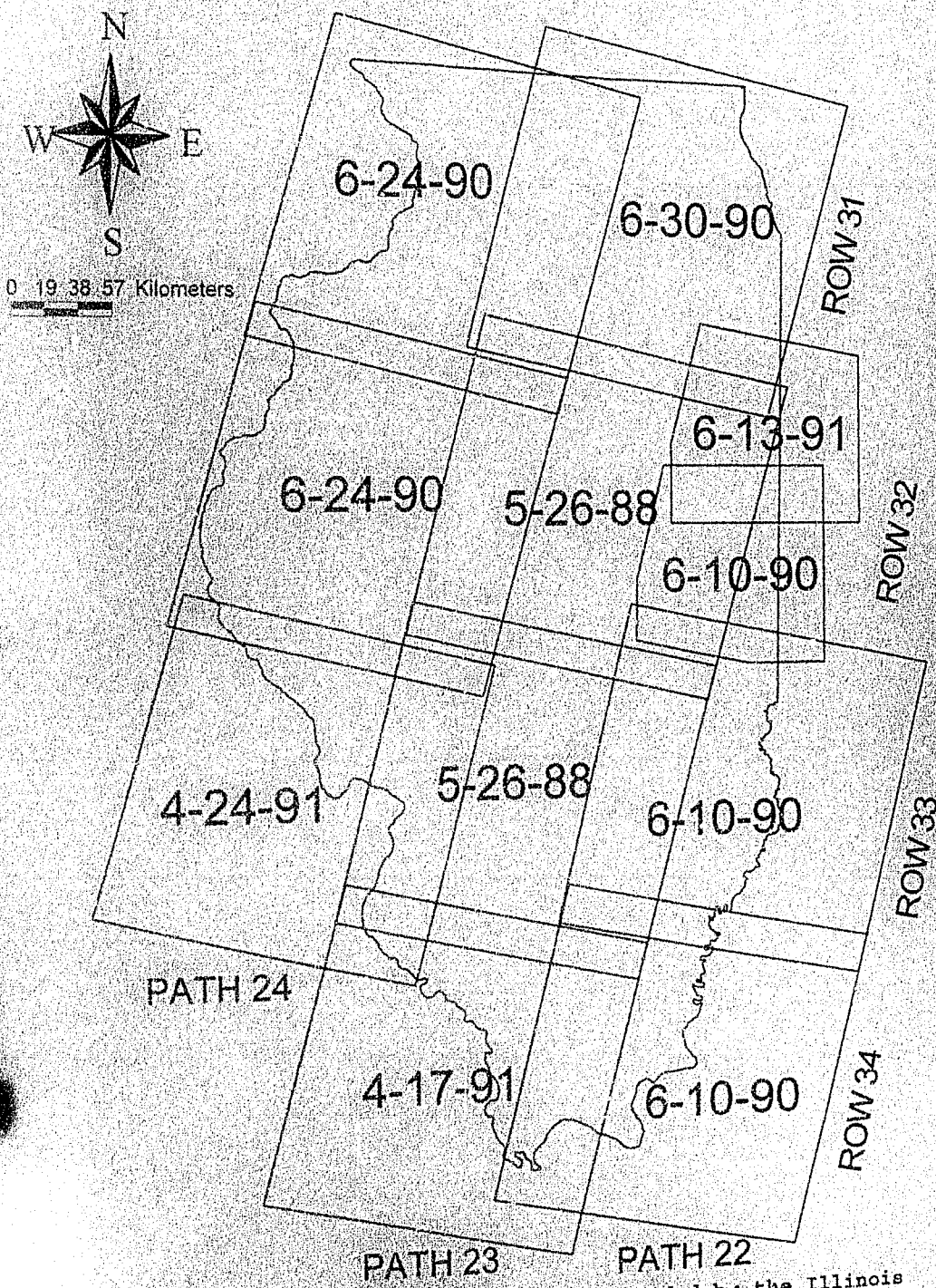

Fig. 1. Satellite coverage of Illinois provided by the Illinois Natural History Survey.

Appendix A. Counties with greater than 48 ha of orchards were digitized using USGS 1:24000-scale topographical quadrangle maps supplied by Morris Library. These 23 counties represent 73% of land in orchards. Cumberland County quad maps were unavailable (51.8 ha). The orchard vectors were merged into a single vector and then converted to a raster for each county.

County	Quad	Quad year	Area ha[a]
Union			730.5
	Anna	1978	
	Cobden	1990	
	Makanda	1990	
	Mill Creek	1990	
Jackson			552.8
	Carbondale	1990	
	Cobden	1990	
	Elkville	1978	
	Makanda	1990	
	Murphysboro	1978	
	Pomona	1990	
	Willisville	1968	
Calhoun			448.4
	Brussels	1974	
	Foley	1975	
	Hamburg	1978	
	Kampsville	1980	
St. Clair			241.6
	Cahokia	1974	
	Collinsville	1974	
	Columbia	1979	
	Freeburg	1974	
	French Village	1982	
	Mascoutah	1990	
Jersey			159.5
	Alton	1974	
	Brussels	1974	
	Elsah	1974	
	Grafton	1974	
	Hardin	1978	
	Nutwood	1975	
	Otterville	1983	
Pike			135.6
	Barry	1978	
	Pearl East	1980	
	Pearl West	1980	
	Summer Hill	1981	

Appendix A. Continued.

County	Quad	Quad year	Area ha[a]
Adams			132.3
	Lima	1981	
	Long Island	1981	
	Loraine	1981	
	Quincy East	1971	
	Quincy West	1971	
	Richfield	1981	
	Tioga	1981	
Macoupin			97.9
	Carlinville West	1979	
	Plainview	1974	
McHenry			90.7
	Hebron	1972	
	Fox Lake	1993	
	Marengo North	1970	
Will			85.0
	Joliet	1973	
Jefferson			83.8
	Harmony	1965	
	Irvington	1974	
	Kell	1978	
	Mount Vernon	1978	
	Walnut Hill	1974	
Marion			81.7
	Centralia East	1970	
	Harmony	1965	
	Irvington	1974	
	Iuka	1965	
	Kell	1978	
	Salem North	1978	
	Salem South	1978	
Lake			70.4
	Antioch	1993	
	Grayslake	1993	
	Libertyville	1993	
Madison			63.5
	Bethalto	1974	
	Collinsville	1974	
	Elsah	1974	
	Worden	1982	
Randolph			63.5
	Coulterville	1982	
	Kaskaskia	1982	
	Chester	1970	

Appendix A. Continued.

County	Quad	Quad year	Area ha[a]
Wayne			60.3
	Bluford	1973	
Rock Island			58.7
	Fort Byron	1991	
	Milan	1992	
	Silvis	1991	
Marshall			56.7
	Castleton	1983	
	La Prairie Center	1983	
Franklin			55.8
	Christopher	1968	
	Harco	1963	
	Johnston City	1976	
	Macedonia	1974	
	Pittsburg	1963	
	Rend Lake Dam	1975	
	Sesser	1975	
	Thompsonville	1976	
	West Frankfort	1978	
Winnebago			55.0
	Ridott	1971	
	South Beloit	1993	
Hancock			50.6
	Augusta	1981	
	Nauvoo	1975	
	Niota	1964	
	Tioga	1981	
Johnson			49.0
	Creal Springs	1976	
	Cypress	1966	
	Goreville	1990	
	Stonefort	1961	
Massac			48.6
	Metropolis	1990	

[a]U.S. Department of Commerce, 1994. 1992 Census of Agriculture. Vol 1 Part 13. Illinois state and county data.

Appendix B. Accuracy assessment and error estimates[a] for Illinois counties classified from Landsat 5 TM satellite data.

Land Use Class[b]	Classified Map					Error (%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Adams County								
Crop	21	4	0	0	25	15.0	28.0	84.0
Grass	7	21	0	0	28	25.0	17.9	75.0
Woods	0	0	21	0	21	0.0	0.0	100.0
Water	0	1	0	13	14	7.1	0.0	92.9
Sum	28	26	21	13	88			
Overall Accuracy: 86% Kappa: 0.81								
Alexander County - no accuracy assessment								
Bond County - no accuracy assessment								
Boone County								
Crop	31	0	0	0	31	0.0	9.7	100.0
Grass	1	23	0	0	24	4.2	0.0	95.8
Woods	0	0	26	0	26	0.0	0.0	100.0
Water	2	0	0	7	9	22.2	0.0	77.8
Sum	34	23	26	7	90			
Overall Accuracy: 97% Kappa: 0.95								
Brown County								
Crop	24	2	0	0	26	7.7	19.2	92.3
Grass	5	18	0	0	23	21.7	8.7	78.3
Woods	0	0	23	0	23	0.0	0.0	100.0
Water	0	0	0	10	10	0.0	10.0	100.0
Sum	29	20	23	10	82			
Overall Accuracy: 92% Kappa: 0.88								

Appendix B. Continued.

Land Use Class	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
Bureau County								
Crop	37	0	1	0	38	2.6	21.1	97.4
Grass	8	18	0	0	26	30.8	0.0	69.2
Woods	0	0	16	0	16	0.0	6.3	100.0
Water	0	0	0	9	9	0.0	0.0	100.0
Sum	45	18	17	9	89			

Overall Accuracy: 90% Kappa: 0.85

Calhoun County - no accuracy assessment

Carroll County								
Crop	16	1	0	0	17	5.9	5.9	94.1
Grass	1	18	0	0	19	5.3	10.5	94.7
Woods	0	1	16	0	17	5.9	0.0	94.1
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	17	20	16	6	59			

Overall Accuracy: 95% Kappa: 0.93

Cass County								
Crop	30	1	0	0	31	3.2	16.1	96.8
Grass	5	14	0	0	19	26.3	5.3	73.7
Woods	0	0	17	0	17	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	35	15	17	11	78			

Overall Accuracy: 92% Kappa: 0.89

Champaign County								
Crop	36	0	0	0	36	0.0	11.1	100.0
Grass	3	14	0	0	17	17.7	0.0	82.4
Woods	1	0	11	0	12	8.3	0.0	91.7
Water	0	0	0	10	10	0.0	0.0	100.0
Sum	40	14	11	10	75			

Overall Accuracy: 95% Kappa: 0.92

Appendix B. Continued.

Land Use Class	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Christian County								
Crop	25	2	0	0	27	7.4	7.4	92.6
Grass	2	11	0	0	13	15.4	15.4	84.6
Woods	0	0	14	0	14	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	27	13	14	6	60			

Overall Accuracy: 93% Kappa: 0.90

Clark County								
Crop	24	0	0	0	24	0.0	33.3	100.0
Grass	7	10	1	0	18	44.4	5.6	55.6
Woods	0	1	23	0	24	4.2	4.2	95.8
Water	1	0	0	8	9	11.1	0.0	88.9
Sum	32	11	24	8	75			

Overall Accuracy: 87% Kappa: 0.81

Clay County								
Crop	23	1	0	0	24	4.2	25.0	95.8
Grass	6	9	0	0	15	40.0	13.3	60.0
Woods	0	0	15	0	15	0.0	0.0	100.0
Water	0	1	0	6	7	14.3	0.0	85.7
Sum	29	11	15	6	61			

Overall Accuracy: 87% Kappa: 0.81

Clinton County								
Crop	24	2	0	0	26	7.7	23.1	92.3
Grass	6	13	1	0	20	35.0	10.0	65.0
Woods	0	0	14	0	14	0.0	7.1	100.0
Water	0	0	0	9	9	0.0	0.0	100.0
Sum	30	15	15	9	69			

Overall Accuracy: 87% Kappa: 0.82

Appendix B. Continued.

Land Use Class	Classified Map: Crop	Grass	Woods	Water	Sum	Error (%): Omission	Commission	Accuracy (%)
Coles County								
Crop	28	0	0	0	28	0.0	21.4	100.0
Grass	6	10	0	0	16	37.5	0.0	62.5
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	34	10	13	11	68			
Overall Accuracy: 91%				Kappa: 0.87				
Cook County - no accuracy assessment								
Crawford County								
Crop	19	2	1	0	22	13.6	13.6	86.4
Grass	3	7	0	0	10	30.0	20.0	70.0
Woods	0	0	21	0	21	0.0	4.8	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	22	9	22	8	61			
Overall Accuracy: 90%				Kappa: 0.86				
Cumberland County								
Crop	29	0	0	0	29	0.0	6.9	100.0
Grass	2	14	0	0	16	12.5	0.0	87.5
Woods	0	0	22	0	22	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	31	14	22	6	73			
Overall Accuracy: 97%				Kappa: 0.96				
De Kalb County								
Crop	32	0	0	0	32	0.0	6.3	100.0
Grass	2	10	0	0	12	16.7	0.0	83.3
Woods	0	0	0	0	0	-	-	-
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	34	10	0	6	50			
Overall Accuracy: 96%				Kappa: 0.92				

Appendix B. Continued.

Land Use Class[a]	Classified Map: Crop	Grass	Woods	Water	Sum	Error (%): Omission	Commission	Accuracy (%)
De Witt County								
Crop	33	0	0	0	33	0.0	24.2	100.0
Grass	4	13	0	0	17	23.5	5.9	76.5
Woods	4	1	8	0	13	38.5	0.0	61.5
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	41	14	8	7	70			
Overall Accuracy: 87%			Kappa: 0.80					
Douglas County								
Crop	32	1	0	0	33	3.0	27.3	97.0
Grass	9	7	0	0	16	56.3	6.3	43.8
Woods	0	0	12	0	12	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	41	8	12	5	66			
Overall Accuracy: 85%			Kappa: 0.76					
Du Page County - no accuracy assessment								
Edgar County								
Crop	29	1	0	0	30	3.3	3.3	96.7
Grass	1	21	0	0	22	4.5	9.1	95.5
Woods	0	1	7	0	8	12.5	0.0	87.5
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	30	23	7	7	67			
Overall Accuracy: 96%			Kappa: 0.93					
Edwards County								
Crop	23	1	0	0	24	4.2	16.7	95.8
Grass	3	18	0	0	21	14.3	4.8	85.7
Woods	0	0	22	0	22	0.0	0.0	100.0
Water	1	0	0	11	12	8.3	0.0	91.7
Sum	27	19	22	11	79			
Overall Accuracy: 94%			Kappa: 0.91					

Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Hillingham County								
Crop	22	1	0	0	23	4.3	30.4	95.7
Grass	6	11	0	0	17	35.3	11.8	64.7
Woods	1	0	14	0	15	6.7	0.0	93.3
Water	0	1	0	7	8	12.5	0.0	87.5
Sum	29	23	14	7	63			
Overall Accuracy: 86% Kappa: 0.80								
Fayette County								
Crop	22	0	0	0	22	0.0	22.7	100.0
Grass	5	15	0	0	20	25.0	0.0	75.0
Woods	0	0	19	0	19	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	27	15	19	7	68			
Overall Accuracy: 93% Kappa: 0.90								
Ford County								
Crop	40	0	0	0	40	0.0	5.0	100.0
Grass	2	19	0	0	21	9.5	0.0	90.5
Woods	0	0	9	0	9	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	42	19	9	7	77			
Overall Accuracy: 97% Kappa: 0.96								
Franklin County								
Crop	25	2	0	0	27	7.4	11.1	92.6
Grass	2	15	0	0	17	11.8	11.8	88.2
Woods	1	0	18	0	19	5.3	0.0	94.7
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	28	17	18	7	70			
Overall Accuracy: 93% Kappa: 0.90								

Appendix B. Continued.

Land Use Class	Classified Map					Error (%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Fulton County								
Crop	24	0	0	0	24	0.0	37.5	100.0
Grass	9	11	0	0	20	45.0	15.0	55.0
Woods	0	2	17	0	19	10.5	5.3	89.5
Water	0	1	1	10	12	16.7	0.0	83.3
Sum	33	14	18	10	75			
Overall Accuracy: 83%				Kappa: 0.76				
Gallatin County								
Crop	16	0	0	0	16	0.0	18.8	100.0
Grass	3	19	0	0	22	13.6	0.0	86.4
Woods	0	0	18	0	18	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	19	19	18	7	63			
Overall Accuracy: 95%				Kappa: 0.93				
Greene County - no accuracy assessment								
Grundy County								
Crop	28	2	0	0	30	6.7	3.3	93.3
Grass	1	9	0	0	10	10.0	20.0	90.0
Woods	0	0	14	0	14	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	29	11	14	6	60			
Overall Accuracy: 95%				Kappa: 0.92				
Hamilton County								
Crop	16	2	0	0	18	11.1	0.0	88.9
Grass	0	25	0	0	25	0.0	8.0	100.0
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	13	13	0.0	0.0	100.0
Sum	16	27	20	13	76			
Overall Accuracy: 97%				Kappa: 0.96				

Appendix B. Continued.

Land Use Class	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Hancock County								
Crop	17	0	0	0	17	0.0	5.9	100.0
Grass	1	22	0	0	23	4.3	13.0	95.7
Woods	0	0	9	0	9	0.0	0.0	100.0
Water	0	3	0	1	4	75.0	0.0	25.0
Sum	18	25	9	1	53			
Overall Accuracy: 92% Kappa: 0.88								
Hardin County								
Crop	16	0	0	0	16	0.0	18.8	100.0
Grass	3	19	0	0	22	13.6	0.0	86.4
Woods	0	0	18	0	18	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	19	19	18	7	63			
Overall Accuracy: 95% Kappa: 0.93								
Henderson County								
Crop	21	0	0	0	21	0.0	38.1	100.0
Grass	8	7	0	0	15	53.3	0.0	46.7
Woods	0	0	17	0	17	0.0	5.9	100.0
Water	0	0	1	2	3	33.3	0.0	66.7
Sum	29	7	18	2	56			
Overall Accuracy: 94% Kappa: 0.76								
Henry County								
Crop	38	0	0	0	38	0.0	5.3	100.0
Grass	2	15	0	0	17	11.8	0.0	88.2
Woods	0	0	17	0	17	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	40	15	17	5	77			
Overall Accuracy: 97% Kappa: 0.96								

Appendix B. Continued.

Land Use Class	Classified Map					Error (%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Iroquois County								
Crop	31	0	1	0	32	3.1	6.3	96.9
Grass	2	9	0	0	11	18.2	0.0	81.8
Woods	0	0	9	0	9	0.0	11.1	100.0
Water	0	0	0	4	4	0.0	0.0	100.0
Sum	33	9	10	4	56			
Overall Accuracy: 95% Kappa: 0.91								
Jackson County								
Crop	22	0	0	0	22	0.0	18.2	100.0
Grass	4	17	0	0	21	19.0	0.0	81.0
Woods	0	0	21	0	21	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	26	17	21	11	75			
Overall Accuracy: 95% Kappa: 0.93								
Jasper County								
Crop	23	1	0	0	24	4.2	25.0	95.8
Grass	6	9	0	0	15	40.0	13.3	60.0
Woods	0	0	15	0	15	0.0	0.0	100.0
Water	0	1	0	6	7	14.0	0.0	85.7
Sum	29	11	15	6	61			
Overall Accuracy: 87% Kappa: 0.81								
Jefferson County								
Crop	22	1	0	0	23	4.3	39.1	95.7
Grass	9	12	0	0	21	42.9	4.8	57.1
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	31	13	20	11	75			
Overall Accuracy: 87% Kappa: 0.82								

Appendix B. Continued.

Land Use Class	Classified Map: Crop	Grass	Woods	Water	Sum	Error (%): Omission	Commission	Accuracy (%)
Jersey County								
Crop	31	0	0	0	31	0.0	9.7	100.0
Grass	3	14	0	0	17	17.6	0.0	82.4
Woods	0	0	22	0	22	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	34	14	22	8	78			
Overall Accuracy: 96%				Kappa: 0.94				
Jo Daviess County								
Crop	16	1	0	0	17	5.9	5.9	94.1
Grass	1	18	0	0	19	5.3	10.5	94.7
Woods	0	1	16	0	17	5.9	0.0	94.1
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	17	20	16	6	[illegible]			
Overall Accuracy: 95%				Kappa: 0.93				
Johnson County								
Crop	7	1	0	0	8	12.5	25.0	87.5
Grass	2	21	0	0	23	8.7	4.3	91.3
Woods	0	0	25	0	25	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	9	22	25	8	64			
Overall Accuracy: 95%				Kappa: 0.9[illegible]				
Kane County								
Crop	26	0	0	0	26	0.0	11.5	100.0
Grass	3	12	0	0	15	20.0	0.0	80.0
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	29	12	13	6	60			
Overall Accuracy: [illegible]5%				Kappa: 0.93				

Appendix B. Continued.

Land Use Class	Classified Map					Error (%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Kankakee County								
Crop	34	0	0	0	34	0.0	11.8	100.0
Grass	4	12	0	0	16	25.0	0.0	75.0
Woods	0	0	0	0	0	-	-	-
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	38	12	0	6	56			
Overall Accuracy: 93% Kappa: 0.86								
Kendall County								
Crop	32	0	1	0	33	3.0	3.0	97.0
Grass	12	2	0	0	14	85.7	0.0	14.3
Woods	1	0	8	0	9	11.1	11.1	88.9
Water	0	0	0	4	4	0.0	0.0	100.0
Sum	45	2	9	4	60			
Overall Accuracy: 77% Kappa: 0.58								
Knox County - no accuracy assessment								
Lake County - no accuracy assessment								
La Salle County								
Crop	26	0	0	0	26	0.0	30.8	100.0
Grass	8	14	0	0	22	36.4	0.0	63.6
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	34	14	13	7	68			
Overall Accuracy: 88% Kappa: 0.83								

Appendix B. Continued.

Land Use Class	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Lawrence County								
Crop	22	0	0	0	22	0.0	18.2	100.0
Grass	2	15	1	0	18	16.7	5.6	83.3
Woods	0	1	19	0	20	5.0	10.0	95.0
Water	2	0	1	3	6	50.0	0.0	50.0
Sum	26	16	21	3	66			
Overall Accuracy: 89% Kappa: 0.85								
Lee County								
Crop	34	0	0	0	34	0.0	11.8	100.0
Grass	4	11	0	0	15	26.7	0.0	73.3
Woods	0	0	22	0	22	0.0	0.0	100.0
Water	0	0	0	12	12	0.0	0.0	100.0
Sum	38	11	22	12	83			
Overall Accuracy: 95% Kappa: 0.93								
Livingston County								
Crop	31	0	0	0	31	0.0	12.9	100.0
Grass	4	11	0	0	15	26.7	0.0	73.3
Woods	0	0	7	0	7	0.0	0.0	100.0
Water	0	0	0	3	3	0.0	0.0	100.0
Sum	35	11	7	3	56			
Overall Accuracy: 93% Kappa: 0.88								
Logan County								
Crop	35	0	0	0	35	0.0	8.6	100.0
Grass	2	14	0	0	16	12.5	0.0	87.5
Woods	0	0	15	0	15	0.0	0.0	100.0
Water	1	0	0	7	8	12.5	0.0	87.5
Sum	38	14	15	7	74			
Overall Accuracy: 96% Kappa: 0.94								

Appendix B. Continued.

Land Use Class*	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Macon County								
Crop	28	0	0	0	28	0.0	3.6	100.0
Grass	1	9	0	0	10	10.0	0.0	90.0
Woods	0	0	6	0	6	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	29	9	6	6	50			
Overall Accuracy: 98% Kappa: 0.97								
Macoupin County								
Crop	23	1	0	0	24	4.2	12.5	95.8
Grass	3	17	0	0	20	15.0	5.0	85.0
Woods	0	0	19	0	19	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	26	18	19	7	70			
Overall Accuracy: 94% Kappa: 0.92								
Madison County								
Crop	29	3	0	0	32	9.4	9.4	90.6
Grass	3	13	0	0	16	18.8	25.0	81.3
Woods	0	1	14	0	15	6.7	0.0	93.3
Water	0	0	0	12	12	0.0	0.0	100.0
Sum	32	17	14	12	75			
Overall Accuracy: 91% Kappa: 0.87								
Marion County								
Crop	21	1	0	0	22	4.5	27.3	95.5
Grass	6	12	0	0	18	33.3	5.6	66.7
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	12	12	0.0	0.0	100.0
Sum	27	13	20	12	72			
Overall Accuracy: 90% Kappa: 0.87								

Appendix B. Continued.

Land Use Class*	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Marshall County								
Crop	33	0	0	0	33	0.0	6.1	100.0
Grass	2	8	0	0	10	20.0	0.0	80.0
Woods	0	0	8	0	8	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	35	8	8	5	56			
Overall Accuracy: 96% Kappa: 0.94								
Mason County								
Crop	30	1	0	0	31	3.2	45.2	96.8
Grass	14	5	0	0	19	73.7	5.3	26.3
Woods	0	0	16	0	16	0.0	6.3	100.0
Water	0	0	1	12	13	7.7	0.0	92.3
Sum	44	6	17	12	79			
Overall Accuracy: 80% Kappa: 0.71								
Massac County								
Crop	24	0	0	0	24	0.0	16.7	100.0
Grass	4	24	0	0	28	14.3	0.0	85.7
Woods	0	0	30	0	30	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	28	24	30	6	88			
Overall Accuracy: 96% Kappa: 0.94								
McDonough County								
Crop	24	0	0	0	24	0.0	37.5	100.0
Grass	9	11	0	0	20	45.0	15.0	55.0
Woods	0	2	17	0	19	10.5	5.3	89.5
Water	0	1	1	10	12	16.7	0.0	83.3
Sum	33	14	18	10	75			
Overall Accuracy: 83% Kappa: 0.76								

Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
McHenry County - no accuracy assessment								
McLean County - no accuracy assessment								
Menard County - no accuracy assessment								
Mercer County - no accuracy assessment								
Monroe County								
Crop	20	1	0	0	21	4.8	33.3	95.2
Grass	7	12	0	0	19	36.8	5.3	63.2
Woods	0	0	17	0	17	0.0	0.0	100.0
Water	0	0	0	12	12	0.0	0.0	100.0
Sum	27	13	17	12	69			
Overall Accuracy: 88% Kappa: 0.84								
Montgomery County								
Crop	16	1	0	0	17	5.9	23.5	94.1
Grass	4	9	0	0	13	30.8	15.4	69.2
Woods	0	1	15	0	16	6.3	0.0	93.7
Water	0	0	0	9	9	0.0	0.0	100.0
Sum	20	11	15	9	55			
Overall Accuracy: 89% Kappa: 0.85								
Morgan County								
Crop	27	1	0	0	28	3.6	14.3	96.4
Grass	4	13	0	0	17	23.5	5.9	76.5
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	10	20	0.0	0.0	100.0
Sum	31	14	20	10	75			
Overall Accuracy: 93% Kappa: 0.91								

Appendix B. Continued.

Land Use Class	Classified Map: Crop	Grass	Woods	Water	Sum	Error (%): Omission	Commission	Accuracy (%)
Moultrie County - no accuracy assessment								
Ogle County								
Crop	23	0	0	0	23	0.0	17.4	100.0
Grass	2	20	2	0	24	16.7	4.2	83.3
Woods	0	1	14	0	15	6.7	13.3	93.3
Water	2	0	0	7	9	22.2	0.0	77.8
Sum	27	21	16	7	71			
Overall Accuracy: 90% Kappa: 0.86								
Peoria County								
Crop	25	0	0	0	25	0.0	4.0	100.0
Grass	1	10	0	0	11	9.1	0.0	90.9
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	26	10	13	11	60			
Overall Accuracy: 98% Kappa: 0.98								
Perry County								
Crop	24	1	0	0	25	4.0	12.0	96.0
Grass	3	15	0	0	18	16.7	5.6	83.3
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	16	16	0.0	0.0	100.0
Sum	27	16	20	16	79			
Overall Accuracy: 95% Kappa: 0.93								
Piatt County								
Crop	29	0	0	0	29	0.0	6.9	100.0
Grass	2	21	0	0	23	8.7	0.0	91.3
Woods	0	0	10	0	10	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	31	21	10	8	[illegible]			
Overall Accuracy: 97% Kappa: 0.96								

Appendix B. Continued.

Land Use Class	Classified Map: Crop	Grass	Woods	Water	Sum	Error (%): Omission	Commission	Accuracy (%)
Pike County								
Crop	24	1	0	0	25	4.0	8.0	96.0
Grass	2	19	0	0	21	9.5	4.8	90.5
Woods	0	0	23	0	23	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	26	20	23	8	77			
Overall Accuracy: 96% Kappa: 0.95								
Pope County								
Crop	7	1	0	0	8	12.5	25.0	87.5
Grass	2	21	0	0	23	8.7	4.3	91.3
Woods	0	0	25	0	25	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	9	22	25	8	64			
Overall Accuracy: 95% Kappa: 0.93								
Pulaski County								
Crop	23	0	1	0	24	4.2	4.2	95.8
Grass	1	17	0	0	18	5.6	5.6	94.4
Woods	0	1	17	0	18	5.6	5.6	94.4
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	24	18	18	11	71			
Overall Accuracy: 96% Kappa: 0.94								
Putnam County								
Crop	3	0	0	0	33	0.0	6.1	100.0
Grass	2	8	0	0	10	20.0	0.0	80.0
Woods	0	0	8	0	8	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	35	8	8	5	56			
Overall Accuracy: 96% Kappa: 0.94								

Appendix B. Continued.

Land Use Class[b]	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
Randolph County								
Crop	23	1	0	0	24	4.2	8.3	95.8
Grass	2	16	0	0	18	11.1	11.1	88.9
Woods	0	1	21	0	22	4.5	0.0	95.5
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	25	18	21	11	75			
Overall Accuracy: 95%				Kappa: 0.93				
Richland County								
Crop	24	1	0	0	25	4.0	20.0	96.0
Grass	5	11	0	0	16	31.2	6.3	68.8
Woods	0	0	22	0	22	0.0	0.0	100.0
Water	0	0	0	10	10	0.0	0.0	100.0
Sum	29	12	22	10	73			
Overall Accuracy: 92%				Kappa: 0.89				
Rock Island County								
Crop	30	1	0	0	31	3.2	9.7	96.8
Grass	3	18	0	0	21	14.3	4.8	85.7
Woods	0	0	16	0	16	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	33	19	16	7	75			
Overall Accuracy: 95%				Kappa: 0.92				
Saline County								
Crop	20	0	0	0	20	0.0	50.0	100.0
Grass	10	10	0	1	21	52.4	0.0	47.6
Woods	0	0	19	0	19	0.0	0.0	100.0
Water	0	0	0	15	15	0.0	6.7	100.0
Sum	30	10	19	16	75			
Overall Accuracy: 85%				Kappa: 0.80				

Appendix B. Continued.

Land Use Class[a]	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
Sangamon County								
Crop	40	1	0	0	41	2.4	2.4	97.6
Grass	1	16	0	0	17	5.9	17.6	94.1
Woods	0	2	16	0	18	11.1	0.0	88.9
Water	0	0	0	13	13	0.0	0.0	100.0
Sum	41	19	16	13	89			
Overall Accuracy: 96% Kappa: 0.93								
Schuyler County								
Crop	23	5	0	0	28	17.9	7.1	82.1
Grass	2	11	0	0	13	15.4	38.5	84.6
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	25	16	20	11	72			
Overall Accuracy: 90% Kappa: 0.87								
Scott County								
Crop	23	2	0	0	25	8.0	4.0	92.0
Grass	1	18	0	0	19	5.3	10.5	94.7
Woods	0	0	21	0	21	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	24	20	21	8	73			
Overall Accuracy: 96% Kappa: 0.94								
Shelby County								
Crop	24	0	0	0	24	0.0	25.0	100.0
Grass	6	13	0	0	19	31.6	10.5	68.4
Woods	0	2	18	0	20	10.0	0.0	90.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	30	15	18	6	69			
Overall Accuracy: 88% Kappa: 0.84								

Appendix B. Continued.

Land Use Class	Classified Map: Crop	Grass	Woods	Water	Sum	Error (%): Omission	Commission	Accuracy (%)
Stark County - no accuracy assessment								
St. Clair County								
Crop	25	0	0	0	25	0.0	12.0	100.0
Grass	3	13	0	0	16	18.8	0.0	81.2
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	28	13	13	6	60			
Overall Accuracy: 95%			Kappa: 0.93					
Stephenson County								
Crop	31	0	1	0	32	3.1	31.3	96.9
Grass	10	15	0	0	25	40.0	0.0	60.0
Woods	0	0	23	0	23	0.0	4.3	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	41	15	24	8	88			
Overall Accuracy: 88%			Kappa: 0.82					
Tazewell County								
Crop	34	0	0	0	34	0.0	8.8	100.0
Grass	3	17	0	0	20	15.0	0.0	85.0
Woods	0	0	11	0	11	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	37	17	11	5	70			
Overall Accuracy: 96%			Kappa: 0.93					
Union County								
Crop	16	3	0	0	19	15.8	10.5	84.2
Grass	2	11	0	0	13	15.4	23.1	84.6
Woods	0	0	16	0	16	0.0	0.0	100.0
Water	0	0	0	12	12	0.0	0.0	100.0
Sum	18	14	16	12	60			
Overall Accuracy: 92%			Kappa: 0.89					

Appendix B. Continued.

Land Use Class[a]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Vermilion County								
Crop	35	0	0	0	35	0.0	5.7	100.0
Grass	2	14	0	0	16	12.5	0.0	87.5
Woods	0	0	8	0	8	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	37	14	8	6	65			
Overall Accuracy: 97% Kappa: 0.95								
Wabash County								
Crop	26	0	0	0	26	0.0	19.2	100.0
Grass	5	11	0	0	16	31.3	0.0	68.7
Woods	0	0	16	0	16	0.0	0.0	100.0
Water	0	0	0	10	10	0.0	0.0	100.0
Sum	31	11	16	10	68			
Overall Accuracy: 93% Kappa: 0.90								
Warren County								
Crop	19	0	0	0	19	0.0	36.8	100.0
Grass	6	10	0	0	16	37.5	0.0	62.5
Woods	1	0	14	0	15	6.7	0.0	93.3
Water	0	0	0	3	3	0.0	0.0	100.0
Sum	26	10	14	3	53			
Overall Accuracy: 87% Kappa: 0.8[illegible]								
Washington County								
Crop	24	1	0	0	25	4.0	28.0	96.0
Grass	6	14	0	0	20	30.0	5.0	70.0
Woods	0	0	21	0	21	0.0	0.0	100.0
Water	1	0	0	11	12	8.3	0.0	91.7
Sum	31	15	21	11	78			
Overall Accuracy: 90% Kappa: 0.86								

Appendix B. Continued.

Land Use Class[a]	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
Wayne County								
Crop	19	2	1	0	22	13.6	45.5	86.4
Grass	10	9	2	0	21	57.1	9.5	42.9
Woods	0	0	20	0	20	0.0	15.0	100.0
Water	0	0	0	16	16	0.0	0.0	100.0
Sum	29	11	23	16	79			
Overall Accuracy: 81%				Kappa: 0.75				
White County								
Crop	15	2	0	0	17	11.8	29.4	88.2
Grass	5	7	0	0	12	41.7	16.7	58.3
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	20	9	13	5	47			
Overall Accuracy: 85%				Kappa: 0.79				
Whiteside County								
Crop	25	1	0	0	26	3.8	19.2	96.2
Grass	5	14	0	0	19	26.3	10.5	73.7
Woods	0	1	18	0	19	5.3	0.0	94.7
Water	0	0	0	1	1	0.0	0.0	100.0
Sum	30	16	18	1	65			
Overall Accuracy: 89%				Kappa: 0.84				
Will County								
Crop	22	3	0	0	25	12.0	0.0	88.0
Grass	0	10	0	0	10	0.0	30.0	100.0
Woods	0	0	10	0	10	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	22	13	10	5	50			
Overall Accuracy: 94%				Kappa: 0.91				

Appendix B. Continued.

Land Use Class[b]	Classified Map					Error (%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Williamson County								
Crop	19	3	0	0	22	13.6	27.3	86.4
Grass	6	19	0	0	25	24.0	12.0	76.0
Woods	0	0	23	0	23	0.0	0.0	100.0
Water	0	0	0	10	10	0.0	0.0	100.0
Sum	25	22	23	10	80			
Overall Accuracy: 89% Kappa: 0.85								
Winnebago County								
Crop	31	0	1	0	32	3.1	31.3	96.9
Grass	10	15	0	0	25	40.0	0.0	60.0
Woods	0	0	23	0	23	0.0	4.3	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	41	15	24	8	88			
Overall Accuracy: 88% Kappa: 0.82								
Woodford County								
Crop	41	0	1	0	42	2.4	2.4	97.6
Grass	1	11	0	0	12	8.3	0.0	91.7
Woods	0	0	9	0	9	0.0	11.1	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	42	11	10	7	70			
Overall Accuracy: 97% Kappa: 0.95								

[a]Calculated according to Congalton 1991.
[b]Ground truth data from Illinois Department of Natural Resources quail and pheasant call count routes.

JOB B. **Deer Ecology and Life History in Westcentral and Northern Illinois**

Objectives: (1) To determine age specific natality and seasonal and annual survival rates for deer in westcentral and northern Illinois; (2) to determine seasonal movement patterns and habitat selection of deer in Westcentral and Northern Illinois; (3) to integrate the natality and survival data collected from this study within new population models for the Illinois deer herd.

This job and its objectives are assigned to the Illinois Natural History Survey and are reported in a separate document.

JOB C. **Population Analysis**

Objectives: (1) To develop interactive, menu-driven, portable computer models and software packages to analyze population data, model herd performance, and predict outcome of alternative harvest strategies on herd size, herd composition, and hunter behavior and success; and (2) to assist the Illinois Department of Natural Resources in integrating this system into their deer management program.

INTRODUCTION

Since the inception of modern firearm deer hunting in 1957, Illinois has required mandatory check-in of all deer harvested. This practice has resulted in perhaps the most extensive and detailed deer harvest data set available to any state agency. The primary purpose of Job C was to assemble this and supplementary information into an accessible database and provide the tools for its analysis.

METHODS

Initial software design was accomplished in close consultation with Division of Wildlife Forest Wildlife Program managers and biologists. Final design and function of the computer programs were based primarily on management needs and data availability. Software was written in Microsoft® FORTRAN version 5.0 and originally compiled on a Gateway 2000 486/66

microcomputer. The program is designed to run on PC-compatible microcomputers using DOS 3.0 or later and i386 or larger processors. The executable file requires 286k of storage and the current data files requires 4.8mb of storage.

RESULTS

Objectives of Job C were met with the development and distribution of the Illinois Deer Harvest Analysis and Modeling Program (IDHAMP). This menu-driven PC-based computer program is designed to store, retrieve, and analyze historical white-tailed deer harvest data from Illinois and to model and simulate alternative future harvest strategies. The program can retrieve certain basic shotgun harvest data from 1957 to the present. Harvest data can also be retrieved separately for archery, muzzleloader, and handgun seasons. Data can be retrieved and examined by individual county, special area, management region, or statewide. Data also can be retrieved by day of season or permit type. Selected data output includes percent hunter success, sex/age composition of the harvest, fawn:doe ratios, population sex ratios, indices of male mortality rates and female harvest rates, potential prevalence of trophy males (≥3.5 years old), and hunter and harvest densities per square mile of total area and woods. Estimates of population size and trends based on population reconstruction, kill/effort, various sex/age harvest indices, and population modeling are also available in graphic or tabular form. Alternative harvest strategies also can be

simulated and evaluated using the program's modeling capabilities. A modified version of IDHAMP that does not include modeling capabilities also was produced and distributed.

Two user's manuals describing all program functions and how to use them are appended to this report. Also appended is a programmer's guide which includes a description of all program subroutines, a list of all variable names and their definitions, and the complete source code for IDHAMP.

JOB D. Analyze and Report

Objectives: (1) To analyze results and prepare products from Jobs A and B; and (2) report and discuss findings and present products in a timely manner.

Objectives for this job were met by development of the products to meet the objectives of Jobs A and C, and timely reporting of progress by means of quarterly progress reports and annual performance reports. Also, meetings were held with Division of Wildlife Resources Forest Wildlife Program staff to implement software application. Finally, Roseberry presented the following paper at the 19[illegible]5 SE Deer Study Group meeting:

Roseberry, J. L., P. [illegible]helton, J. Kube, and A. Woolf. 1995. Computer assisted management of white-tailed deer in Illinois. 18th Ann. Meeting of the Southeastern Deer Study Group, San Antonio, TX. February 26-28, 1995.

Illinois Deer Harvest Analysis and Modeling Program (IDHAMP)

Version 1.1

User's Guide and Reference Manual

Developed for

The Illinois Department of Conservation

by

John L. Roseberry

Cooperative Wildlife Research Laboratory
Southern Illinois University at Carbondale

1995

TABLE OF CONTENTS

SECTION I: HOW TO USE IDHAMP

Introduction

The Illinois Deer Harvest Analysis and Modeling Program (IDHAMP) is a menu-driven, PC-based computer program designed to retrieve, analyze, and display historical white-tailed deer harvest data from Illinois (Fig. 1). The program also has population modeling and harvest simulation capabilities. The general protocol for using IDHAMP is to select an area, task, and time period in that order.

To begin a session, change to the subdirectory containing **idhamp.exe** and the data files, and type **IDHAMP** at the DOS command prompt. Following the initial logo, the first interactive screen to appear will be the AREA LIST. From here, you can select an individual county, special area, management region (Fig. 2), or the entire state for data retrieval or modeling. A "new" (user-defined) area also can be designated for simulating harvest regimes.

After you have selected an area, the MAIN MENU appears with the following choices:

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                                     *
*          (1) SHOTGUN HARVEST DATA                                   *
*          (2) ARCHERY HARVEST DATA                                   *
*          (3) MUZZLELOADER HARVEST DATA                              *
*          (4) HANDGUN HARVEST DATA                                   *
*          (5) MODEL PAST TRENDS                                      *
*          (6) MODEL HARVEST STRATEGIES                               *
*                                                                     *
* (R)ETURN or (Q)UIT                                                  *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

These options are described below under separate headings of Data Retrieval (Options 1-4) and Modeling (Options 5-6).

Data Retrieval

Shotgun

MAIN MENU Option 1 (**SHOTGUN HARVEST DATA**) displays the SHOTGUN SUBMENU with the following choices:

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                (1) KILL BY SEX/AGE CLASS                              *
*                (2) VITAL STATISTICS                                   *
*                (3) SUCCESS BY PERMIT TYPE                             *
*                (4) KILL BY DAY OF SEASON                              *
*                (5) HUNTER/HARVEST DENSITY                             *
*                                                                       *
* (R)ETURN or (Q)UIT                                                    *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

Data provided by these options are:

Kill by Sex/Age Class.--Annual shotgun hunter harvest for males and females aged 0.5, 1.5, 2.5, 3.5, and 4.5+ years (Appendix A, Table 1).

Vital Statistics.--Annual numerical harvest, number of fawns/100 does, estimated adult female:male ratio in population, percent females in harvest, percent 1.5-year-olds among harvested males 1.5 and older, and percent 3.5+ males in the total harvest (Appendix A, Table 2).

Success by Permit Type.--Selection of this option brings up the SHOTGUN PERMIT LIST with the following choice of individual permit types and combinations:

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                (1) REGULAR/FULL/EITHER                                *
*                (2) REGULAR/2ND/EITHER                                 *
*                (3) REGULAR/FULL/ANTLERED                              *
*                (4) REGULAR/FULL/ANTLERLESS                            *
*                (5) REGULAR/2ND/ANTLERLESS                             *
*                (6) PAID/FULL/EITHER                                   *
*                (7) PAID/FULL/ANTLERLESS                               *
*                (8) FREE/FULL/EITHER                                   *
*                (9) FREE/FULL/ANTLERLESS                               *
*               (10) ALL REGULAR                                        *
*               (11) ALL PAID                                           *
*               (12) ALL FREE                                           *
*               (13) ALL FULL/EITHER                                    *
*               (14) ALL FULL/ANTLERLESS                                *
*               (15) ALL FULL                                           *
*               (16) ALL 2ND
```

```
*            (17) ALL PERMITS COMBINED                    *
*            (18) ALL PERMITS INDIVIDUALLY                *
*                                                         *
* (R)ETURN or (Q)UIT                                      *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

Selection of any of the above permit types produces a table listing the permit type, number issued, deer harvested, percent success, and sex/age breakdown of the kill (Appendix A Table 3).

Kill by Day of Season.--Provides the following information for each day of the season and by 1st and 2nd weekend and total season: kill, percent of total kill, cumulative percent, percent fawns, females, and 2.5+ males (Appendix A, Table 4).

Hunter/Harvest Density.--Numbers of hunters afield and deer killed per square mile of total area and forest. Harvest density given for antlered and antlerless classes and total harvest. Hunter density is based on the number of 1st season opening day permits and thus represents the maximum potential density (Appendix A, Table 5).

Once you have defined a data retrieval task, you are prompted for a time period with the command:

ENTER LAST 2 DIGITS OF FIRST AND LAST YEAR (57-94):

Enter years as 2 digit numbers separated by a blank or a dash. The years in ( ) indicate the maximum available data range for the specified task and season type. Some areas have additional data restrictions for which you will be alerted.

At the bottom of each data screen, you are given the option to print the results, save them to a file, or continue:

(P)RINT, (S)AVE, or (C)ONTINUE

If you select SAVE (S or s), you are prompted to:

ENTER OUTPUT FILE NAME AND PATH:

If you select CONTINUE (C or c), you are given the opportunity to return to the:

(A)REA LIST, (M)AIN MENU, (L)AST MENU, (Q)UIT

Archery

Selecting Option 2 from the MAIN MENU (ARCHERY HARVEST DATA) displays the ARCHERY SUBMENU with the following choices:

```
*************************************************
*          (1) HARVEST DATA (BIWEEKLY)          *
*          (2) HARVEST DATA (SEASON)            *
*          (3) SUCCESS BY PERMIT TYPE           *
*          (4) HUNTER/HARVEST DENSITY           *
*                                               *
* (R)ETURN or (Q)UIT                            *
*************************************************
```

Harvest Data (Biweekly).--Biweekly archery harvest of males, females and unknown sex deer. Also the percent females in harvest, percent of total harvest, and cumulative percent for each biweekly period (Appendix A, Table 6).

Harvest Data (Season).--Total season archery kill of males, females, unknowns, and all deer. Also provides the percent females in harvest (Appendix A, Table 7).

Success by Permit Type.--Selection of this option brings up the ARCHERY PERMIT LIST with the following choices:

```
*************************************************
*          (1) REGULAR EITHER                   *
*          (2) REGULAR ANTLERED                 *
*          (3) REGULAR ANTLERLESS               *
*          (4) FREE EITHER                      *
*          (5) FREE ANTLERLESS                  *
*          (6) ALL PERMITS COMBINED             *
*          (7) ALL PERMITS INDIVIDUALLY         *
*                                               *
* (R)ETURN or (Q)UIT                            *
*************************************************
```

Selection of any of the above permit types produces a table listing the permit type, number issued, deer harvested, percent success, and sex breakdown of the kill (Appendix A, Table 8).

Hunter/Harvest Density.--Numbers of bow hunters and their harvest per square mile of total area and forest. Harvest density is available for all areas; hunter density data is available Statewide only (Appendix A, Table 9).

Muzzleloader

Selecting MAIN MENU Option 3 (MUZZLELOADER HARVEST DATA) displays the MUZZLELOADER SUBMENU with the following choices:

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                (1) HARVEST BY SEX                                     *
*                (2) HARVEST BY DAY                                     *
*                (3) SUCCESS BY PERMIT TYPE                             *
*                (4) HUNTER/HARVEST DENSITY                             *
*                                                                       *
* (R)ETURN or (Q)UIT                                                    *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

Harvest by Sex.--Total muzzleloader harvest, the number of males, females, and unknown sex and the percent females in the harvest (Appendix A, Table 7).

Harvest by Day.--Harvest data by day not available through the 1994 season.

Success by Permit Type.--Selecting this option displays the MUZZLELOADER PERMIT LIST with the following choices:

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                (1) REGULAR EITHER                                     *
*                (2) REGULAR ANTLERED                                   *
*                (3) REGULAR ANTLERLESS                                 *
*                (4) FREE EITHER                                        *
*                (5) FREE ANTLERLESS                                    *
*                (6) ALL PERMITS COMBINED                               *
*                (7) ALL PERMITS INDIVIDUALLY                           *
*                                                                       *
* (R)ETURN or (Q)UIT                                                    *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

Selection of any of the above permit types produces a table listing the permit type, number issued, deer harvested, percent success, and sex breakdown of the kill (Appendix A, Table 8).

Hunter/Harvest Density.--Numbers of muzzleloader hunters and their harvest per square mile of total area and forest (Appendix A, Table 9).

Handgun

Selecting MAIN MENU Option 4 (HANDGUN HARVEST DATA) displays the HANDGUN SUBMENU with the following choices:

```
*****************************************
*          (1) HARVEST BY SEX           *
*          (2) HARVEST BY DAY           *
*          (3) SUCCESS BY PERMIT TYPE   *
*          (4) HUNTER/HARVEST DENSITY   *
*                                       *
* (R)ETURN or (Q)UIT                    *
*****************************************
```

Harvest by Sex.--Total handgun harvest, the number of males, females, and unknown sex and the percent females in the harvest (Appendix A, Table 7).

Harvest by Day.--Harvest data by day not available through the 1994 season.

Success by Permit Type.--Selecting this option displays the HANDGUN PERMIT LIST with the following choices:

```
*****************************************
*                                       *
*          (1) REGULAR EITHER           *
*          (2) REGULAR ANTLERED         *
*          (3) REGULAR ANTLERLESS       *
*          (4) FREE EITHER              *
*          (5) FREE ANTLERLESS          *
*          (6) ALL PERMITS COMBINED     *
*          (7) ALL PERMITS INDIVIDUALLY *
*                                       *
* (R)ETURN or (Q)UIT                    *
*****************************************
```

Selection of any of the above permit types produces a table listing the permit type, number issued, deer harvested, percent success, and sex breakdown of the kill (Appendix A, Table 8).

Hunter/Harvest Density.--Numbers of handgun hunters and their harvest per square mile of total area and forest (Appendix A, Table 9).

Modeling

Two separate modeling capabilities are available from the MAIN MENU. **MODEL PAST TRENDS** (Option 5) models county, regional, or statewide population trends for a specified period of years. **MODEL HARVEST STRATEGIES** (Option 6) predicts outcomes of selected harvest strategies.

Model Past Trends

Following selection of this option (MAIN MENU #5), you are prompted to:

ENTER LAST 2 DIGITS OF FIRST AND LAST YEAR (80-94)

then queried:

DO YOU WANT TO SEE/CHANGE PARAMETERS? (Y/N)

An affirmative response (Y or y) displays the PARAMETER SCREEN with values specific to the area being modeled:

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*   (1) MALE FAWN WINTER MORTALITY RATE =                    .060   *
*   (2) FEMALE FAWN WINTER MORTALITY RATE =                  .060   *
*   (3) MALE YEARLING WINTER MORTALITY RATE =                .140   *
*   (4) FEMALE YEARLING WINTER MORTALITY RATE =              .070   *
*   (5) MALE ADULT WINTER MORTALITY RATE =                   .100   *
*   (6) FEMALE ADULT WINTER MORTALITY RATE =                 .070   *
*                                                                   *
*   (7) MALE FAWN SUMMER MORTALITY RATE =                    .110   *
*   (8) FEMALE FAWN SUMMER MORTALITY RATE =                  .090   *
*   (9) MALE YEARLING SUMMER MORTALITY RATE =                .020   *
*   (10) FEMALE YEARLING SUMMER MORTALITY RATE =             .050   *
*   (11) MALE ADULT SUMMER MORTALITY RATE =                  .020   *
*   (12) FEMALE ADULT SUMMER MORTALITY RATE =                .010   *
*                                                                   *
*   (13) FAWN REPRODUCTIVE RATE =                            .750   *
*   (14) YEARLING REPRODUCTIVE RATE =                        1.55   *
*   (15) ADULT REPRODUCTIVE RATE =                           1.80   *
*                                                                   *
*   (16) CARRYING CAPACITY (DEER/SQM WOODS) =                250.0  *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

ENTER NUMBER OF PARAMETER YOU WANT TO ALTER (0 IF NONE):

To alter a parameter value, enter the number of the parameter. You are then prompted for the new value. Repeat until all desired changes have been made. (Note: changes affect only the current session and do not permanently alter the default file). Enter 0 to exit the PARAMETER SCREEN.

You are next prompted for information with the following sequence of commands:

ENTER INITIAL DEER DENSITY (DEER/SQ MILE):
ENTER PERCENT OF AREA CLOSED TO GUN HUNTING:
ENTER PERCENT OF CLOSED AREA OPEN TO BOW HUNTING:
ENTER C:

In subsequent versions of IDHAMP, this information will be stored in the **area.dat** file and read automatically.

Initial deer density (per square mile of total area) refers to the estimated prehunt population density in the first year of the model run. Percent of area closed to gun hunting and percent of this land open to archers should be entered as a percent (not a proportion). "C" is the harvest vulnerability coefficient or proportion of the available population harvested per unit effort.

Results are displayed on the screen in tabular and graphic form. The table reports 3 population indices (reconstruction, Lang/Wood, and kill/unit effort); estimated prehunt size of the vulnerable, protected, and total modeled population; estimated harvest rate of males and females (all weapons plus crippling); and total actual harvest and percent females in the harvest (Appendix A, Table 10).

Display of graphs compare modeled population trends with those derived from reconstruction, Lang/Wood, kill/effort, and reported roadkills (Appendix A, Figure 1). The Y-axis of each graph is scaled to accommodate the largest relative spread of the pair of variables being plotted.

Hitting the "Enter" key from the graphics screen erases the graphs and initiates the following sequence of options to continue or terminate the session:

RUN MODEL WITH SAME COUNTY? (Y/N)
RUN MODEL WITH DIFFERENT COUNTY? (Y/N)
RETURN TO (A)REA LIST, (M)AIN MENU OR (Q)UIT?

Model Harvest Strategies

Selection of this option (MAIN MENU #6) initiates the following sequence of commands:

ENTER SIZE OF AREA IN SQUARE MILES:
ENTER PERCENT FORESTED:
ENTER INITIAL DENSITY (DEER/SQ MILE OF WOODS):
ENTER PERCENT OF AREA CLOSED TO GUN HUNTING:
ENTER PERCENT OF CLOSED AREA OPEN TO BOW HUNTING:

In future versions of IDHAMP, this information will be stored in the **area.dat** file and read automatically when individual counties, regions, or entire state are modeled. In the current version, this information must be entered by the user and the area selected from the AREA LIST must be "new area".

You are next asked:

DO YOU WANT TO SEE/CHANGE PARAMETERS? (Y/N)

Parameters and methods of editing are the same as described for **Modeling Past Trends**.

The next menu to appear offers the following choices of hunting seasons:

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                TYPE OF SEASON                             *
*                                                           *
*                (1) CLOSED (NO HUNTING)                    *
*                (2) BUCKS ONLY                             *
*                (3) ANTLERLESS ONLY                        *
*                (4) ANY DEER                               *
*                (5) COMBINATION                            *
*                                                           *
* (R)ETURN or (Q)UIT                                        *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

Following any selection other than #1, you are given a choice of 3 ways to specify the harvest:

```
*****************************************
*        TYPE OF HARVEST MANAGEMENT       *
*                                         *
*                                         *
*        (1) NUMERICAL (NUMBER HARVESTED) *
*        (2) PROPORTIONAL (HARVEST RATE)  *
*        (3) EFFORT (PERMIT SYSTEM)       *
*                                         *
* (R)ETURN or (Q)UIT                      *
*****************************************
```

You are next prompted for specific harvest parameters depending on type of season and harvest management in effect. For example, an **any deer** season and **proportional** harvest would elicit the following commands:

ENTER HARVEST RATE FOR BUCKS:
ENTER HARVEST RATE FOR DOES:
ENTER HARVEST RATE FOR FAWNS:
ENTER NUMBER OF YEARS IN EFFECT:

For a **combination** season with **effort** harvest, the commands would be:

ENTER BUCK-ONLY PERMITS (FULL SEASON, 2ND ONLY):
ENTER ANTLERLESS-ONLY PERMITS (FULL SEASON, 2ND ONLY):
ENTER ANY-DEER PERMITS (FULL SEASON, 2ND ONLY):
ENTER NUMBER OF YEARS IN EFFECT:

At this point, simulation results appears on the screen (Appendix A, Tables 11). If **EFFORT** (permit) harvest is in effect, results by individual permit type are also displayed (Appendix A, Table 12). After viewing results, you are given the option to:

```
*****************************************
*  (1) CONTINUE RUN WITH SAME HARVEST     *
*  (2) CONTINUE RUN WITH DIFFERENT HARVEST *
*  (3) START NEW RUN                      *
*  (4) CHANGE PARAMETERS                  *
*  (5) DEFINE NEW AREA                    *
*  (6) RETURN TO MAIN MENU                *
*  (7) QUIT                               *
*****************************************
```

If you select Option 1, all current parameters remain in effect and you are requested to:

ENTER NUMBER OF YEARS IN EFFECT:

Option 2 maintains the same type of season and management but requires new rates, numbers, or permits to be entered, e.g.:

ENTER NUMERICAL HARVEST OF BUCKS:
ENTER NUMBER OF YEARS IN EFFECT:

Option 3 offers the opportunity to select a new type of season and management.

Option 4 returns to the PARAMETER LIST.

Option 5 returns to the initial area-descriptor commands.

Options 6 and 7 are self-explanatory.

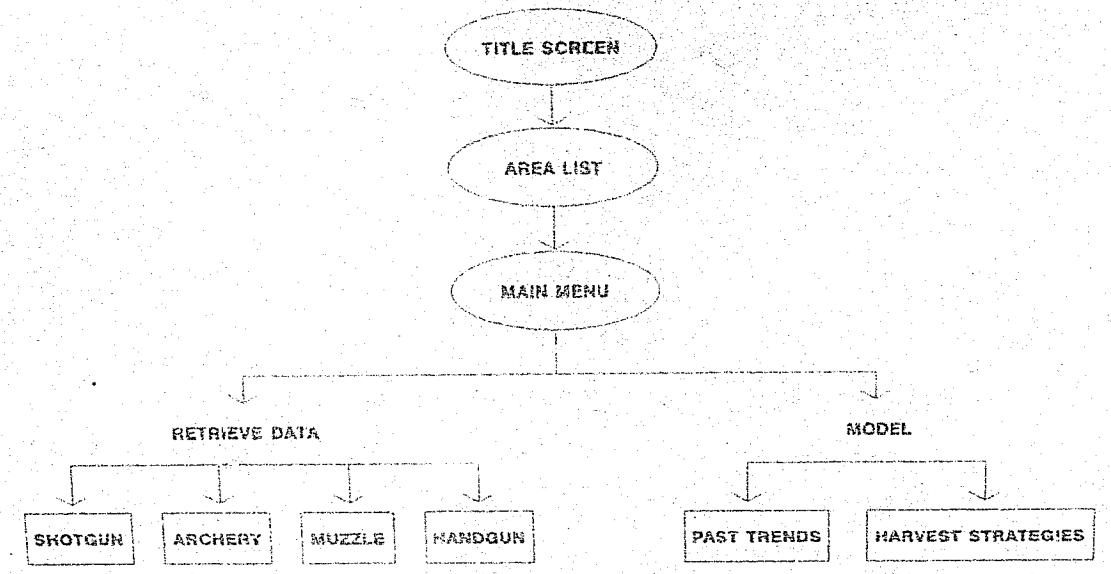

Figure 1. IDHAMP flowchart.

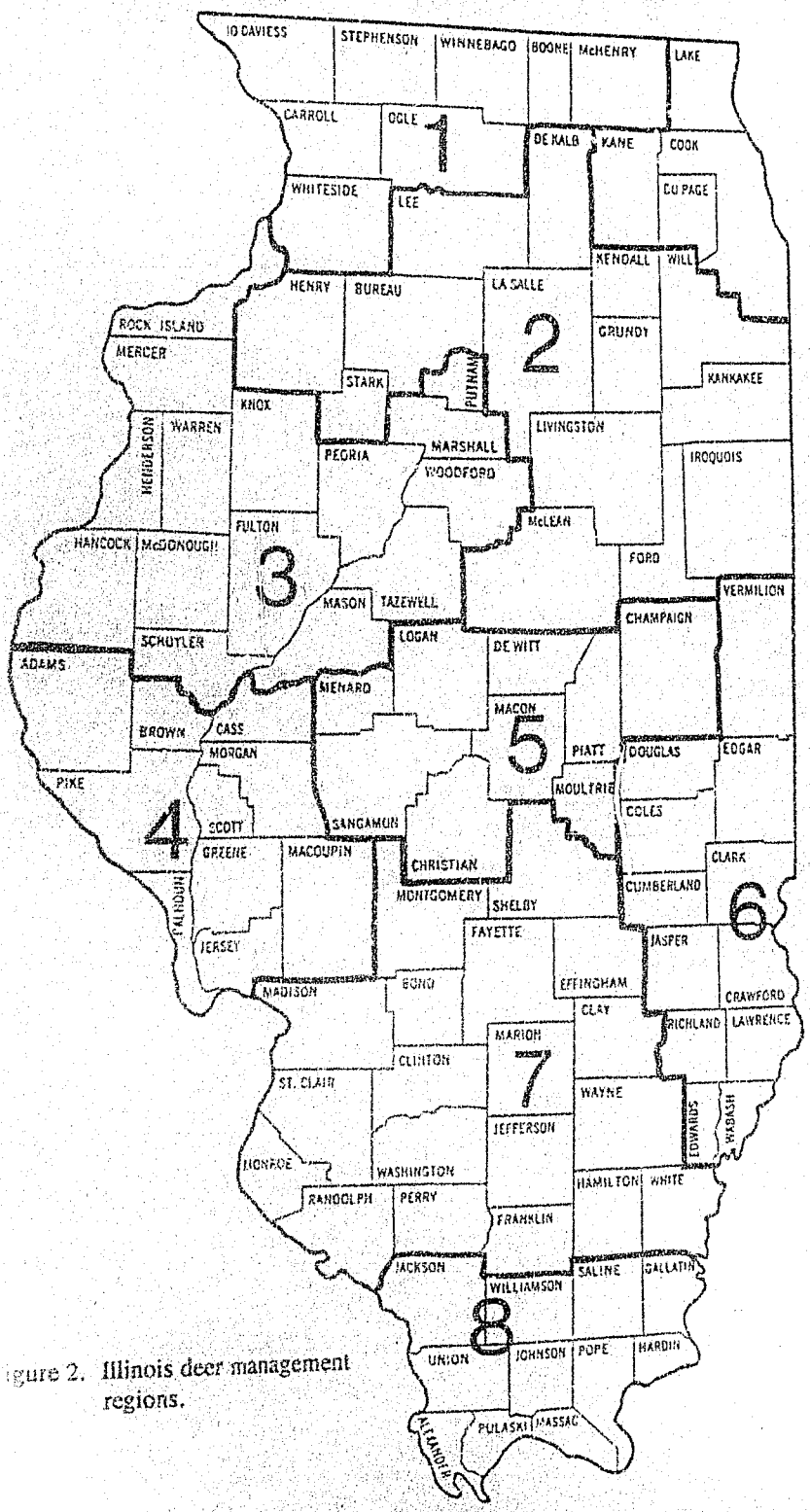

Figure 2. Illinois deer management regions.

SECTION II: POPULATION INDICES AND VITAL STATISTICS

This section briefly describes the various population indices and vital statistics provided by IDHAMP. For a more detailed discussion, see Roseberry and Woolf (1991).

Vital Statistics

Fawns/100 Does.--Number of fawns (male and female) harvested per 100 females age 1.5 and older. This is an index of annual recruitment rates.

Percent Females in Harvest.--Percent of total harvest that was female (including fawns). This may be an index (not an absolute estimate) of the female harvest rate (Laramie and White 1964, Roseberry and Woolf 1991:35-39).

Females per Male in the Adult Population.--Derived by dividing the percent of 1.5-year-olds in the 1.5+ male harvest by the percent of 1.5-year-olds in the 1.5+ female harvest (Severinghaus and Maguire 1955).

Percent Yearlings in Male Harvest.--Percent of male harvest 1.5 and older that was 1.5 years old. This may be an index of annual mortality rates among antlered males (Burgoyne 1981:412, Roseberry and Woolf 1991:32-35).

Percent 3.5+ Males in Harvest.--Percent of total harvest that was males 3.5 years and older. This is an index of the relative proportion of potential trophy bucks in the harvest.

Population Indices

Reconstruction.--Population reconstruction determines the minimum possible number of individuals alive in a given cohort for a given year by summing the annual harvest (all weapons plus estimated crippling loss) of that cohort throughout its lifetime. Prior to doing this, IDHAMP prorates the 4.5+ age class into progressively older age classes. Reconstruction of the 3 most recent years is not attempted because subsequent harvests of younger cohorts are yet to be recorded. Populations for these years are estimated by computing the average harvest rate of the 3 previous years from their reconstructions and harvest and dividing the total annual harvest by this estimated harvest rate. IDHAMP utilizes all available data for reconstruction, regardless of the user-designated time period. In this way, reconstruction estimates for a given year are unaffected by the range of years requested. The basic reconstruction procedure provides a minimum population estimate. IDHAMP divides this figure by the

estimated lifetime recovery rate for males and females to obtain an absolute population estimate. Lifetime recover rates are stored by county in the **area.dat** file.

Lang/Wood.--This procedure, adapted from Lang and Wood (1976), estimates the adult male mortality rate from the shotgun age structure and divides it into the total male harvest from all weapons plus estimated crippling to obtain a male population estimate. A sex ratio is then computed from the harvest composition and applied to the male population estimate to obtain the total adult population. Finally, the fawn:doe ratio from the harvest is combined with the adult population to estimate the number of fawns in the prehunt population. The same male lifetime recover rates used in population reconstruction are also used in this procedure.

Kill/Unit Effort.--This procedure estimates prehunt population size using the following formula:

$$POP = \frac{KILL}{1 - e^{-CE}}$$

where

KILL = number of deer taken with global (any deer/any season) shotgun permits
E = number of global shotgun permits issued
C = proportion of the population taken by 1 permit holder per day
e = natural logarithm

If C is a valid estimate, the procedure produces an actual population estimate; otherwise, it is only an index.

SECTION III: POPULATION AND SIMULATION MODELS

The population model used to analyze past trends and test harvest strategies is basically an accounting procedure that subtracts losses, adds gains, and keeps a running total of the number of animals alive in various sex/age cohorts during successive periods of the annual cycle. The deer population is segregated into 2 groups (hunted and protected). Each group is represented by 6 cohorts (males, females, fawns, yearlings, adults). The 12-month year is divided into 5 intervals representing important seasons or events in the deer's life (hunting season, winter, dispersal, reproductive, and summer). Mortality and reproductive rates are assumed to be density dependent. Carrying capacity is expressed in terms of deer per square mile of forest. Base mortality and reproductive rates can be altered during model runs, as can the proportion of the area closed to gun and bow hunting. Other parameters can be altered by editing the **idhamp.par** file. Interchange between the protected and hunted segments of the population is assumed to take place following winter and prior to fawning season. Only male and female fawns and female yearlings are allowed to disperse. The dispersal rate for fawns is density dependent; that of female yearlings is a constant. The proportion of dispersers that remain within their own area (protected or hunted) is based on the proportion of total area that is closed to hunting.

Harvest routines vary according to whether past trends or future harvest strategies are being modeled. For analysis of past trends, the model begins at some user-designated past year and runs to the present. Actual harvest data (shotgun, archery, muzzleloader, handgun) from the selected study area (county, special area, region, state) are used by the model to represent annual hunter harvests. Prior to 1991, the archery harvest is represented as a percentage of the recorded gun harvest. These percentages are based on 1991-93 data and stored by county in the **area.dat** file. Sex/age specific gun and bow crippling rates are stored in **idhamp.par** and may be altered as desired. For simulation of harvest strategies, the model begins at the present and continues for a specified number of years into the future, with harvesting controlled by the user. Numerical and proportional harvests are simulated by removing a certain number or percentage of the population each year (assumed to include all weapons and crippling). In effort-based harvest regime, the numerical harvest is calculated as:

$$KILL = POP \cdot 1 - e^{-ce}$$

where

KILL = daily harvest
POP = number of deer currently alive

E = number of permits currently valid for that type of animal
c = proportion of the population taken by 1 permit holder per day
e = natural logarithm

A 1-day time step is used in effort harvesting to keep track of available animals and valid permits each day of the season. Daily KILL, POP, and EFFORT are computed separately for antlered, antlerless, and any-deer permits. The daily kill for these classes is apportioned into individual cohorts using regression equations from Roseberry and Woolf (1988). Estimated total natural mortality during the hunting season is apportioned among days of the hunting season and the number of animals available for harvest is reduced accordingly. Seasonal changes in vulnerability and the phenomenon of "no shows" are represented by parameters in **idhamp.par** and may be changed as desired.

SECTION IV: REFERENCES

Burgoyne, G. E., Jr. 1981. Observations on a heavily exploited deer population. Pp. 403-413 in C. W. Fowler and T. D. Smith, eds. Dynamics of large mammal populations. John Wiley and Sons, New York, N.Y.

Lang, L. M., and G. W. Wood. 1976. Manipulation of the Pennsylvania deer herd. Wildl. Soc. Bull. 4:159-165.

Laramie, H. A., Jr., and D. L. W. White. 1964. Observations concerning hunting pressure and harvest on white-tailed deer. N.H. Fish and Game Dep. Tech. Circ. 20. 55pp.

Roseberry, J. L., and A. Woolf. 1988. Evidence for and consequences of deer harvest data biases. Proc. Southeast. Assoc. Fish and Wildl. Agencies. 42:306-314.

Roseberry, J. L., and A. Woolf. 1991. A comparative evaluation of techniques for analyzing white-tailed deer harvest data. Wildl. Monogr. 117, 59pp.

Severinghaus, C. W., and H. F. Maguire. 1955. Use of age composition data for determining sex ratios among adult deer. N.Y. Fish and Game J. 2:242-246.

APPENDIX A. Sample output from IDHAMP.

Table 1. Shotgun harvest data, kill by sex/age class, Adams County, 1990-1993.

	MALES					FEMALES				
YEAR	0.5	1.5	2.5	3.5	4.5+	0.5	1.5	2.5	3.5	4.5+
1990	361	532	235	112	10	289	249	262	75	25
1991	477	557	260	107	12	411	347	328	200	61
1992	493	555	230	125	36	443	365	269	218	91
1993	539	634	295	138	32	438	442	290	211	71

Table 2. Shotgun harvest data, vital statistics, Adams County, 1990-1993.

YEAR	KILL	FAWNS/ 100 DOES	AD FEMALES/ MALE IN POP	PERCENT FEMALE	PERCENT 1.5 AMONG MALES	PERCENT 3.5+ MALES
1990	2150	106.4	1.47	41.9	59.8	5.7
1991	2760	94.9	1.61	48.8	59.5	4.3
1992	2825	99.3	1.52	49.1	58.7	5.7
1993	3090	96.4	1.32	47.0	57.7	5.5

Table 3. Shotgun harvest data, success by permit type, Jo Daviess County, 1993.

YEAR	PERMIT* TYPE	NUMBER ISSUED	KILL	PERCENT SUCCESS	MF	MY	MA	FF	FY	FA
1993	RFE	3700	1339	36.2	199	353	299	163	145	180
1993	PFE	170	65	38.2	7	23	21	3	3	8
1993	FFE	481	132	27.4	14	40	40	12	16	10
1993	R1E	0	0	0.0	0	0	0	0	0	0
1993	R2E	207	33	15.9	7	9	2	6	5	4
1993	RFB	0	0	0.0	0	0	0	0	0	0
1993	RFA	1458	720	49.4	203	10	3	170	145	189
1993	R2A	16	4	25.0	1	0	0	0	1	2
1993	FFA	481	171	35.6	53	0	1	33	39	45

*RFE Regular, full season, either sex
PFE Paid, full season, either sex
FFE Free, full season, either sex
R1E Regular, 1st season, either sex
R2E Regular, 2nd season, either sex
RFB Regular, full season, antlered
RFA Regular, full season, antlerless
R2A Regular, 2nd season, antlerless
FFA Free, full season, antlerless.
MF Male fawns.
MY Male yearlings.
MA Male adults.
FF Female fawns.
FY Female yearlings.
FA Female adults.

Table 4. Shotgun harvest data, kill by day of season, Jo Daviess County, 1991.

YEAR	DAY/ SEASON	KILL	PERCENT OF TOTAL	CUMULATIVE PERCENT	PERCENT FAWNS	PERCENT FEMALES	PERCENT 2.5+ MALES
1991	1	569	25.5	25.5	27.6	38.5	16.7
1991	2	551	24.7	50.1	32.5	44.8	15.8
1991	3	262	11.7	61.9	34.4	50.8	15.6
1991	4	125	5.6	67.5	32.8	44.0	12.8
1991	5	232	10.4	77.8	30.2	55.6	11.6
1991	6	263	11.8	89.6	42.2	59.7	6.8
1991	7	232	10.4	100.0	39.7	60.3	11.6
1991	1ST	1382	61.9		30.8	43.3	16.1
1991	2ND	852	38.1		36.9	56.5	10.3
1991	ALL	2234	100.0		33.1	48.3	13.9

Table 5. Shotgun harvest data, hunter/harvest density, Union County, 1988-1993.

	HUNTER DENSITY		HARVEST DENSITY					
	TOTAL AREA	WOODS	TOTAL AREA			WOODS		
YEAR			BUCKS	OTHER	TOTAL	BUCKS	OTHER	TOTAL
1988	5.6	14.0	1.1	1.2	2.3	2.7	3.0	5.8
1989	5.7	14.5	1.7	1.1	2.8	4.3	2.7	7.0
1990	8.3	20.8	2.0	1.4	3.4	5.0	3.7	8.7
1991	8.1	20.4	2.2	2.4	4.6	5.5	6.1	11.7
1992	11.0	27.7	2.3	2.6	4.9	5.8	6.6	12.4
1993	11.9	30.0	2.3	2.8	5.1	5.8	7.1	12.9

Table 6. Archery harvest data, biweekly, Madison County, 1993.

YEAR	BIWEEKLY PERIOD	MALE	FEMALE	UNKNOWN	PERCENT FEMALE	PERCENT TOTAL KILL	CUMULATIVE PERCENT
1993	1	20	32	0	61.5	20.5	20.5
1993	2	27	18	1	40.0	18.1	38.6
1993	3	62	25	0	28.7	34.3	72.8
1993	4	23	15	0	39.5	15.0	87.8
1993	5	6	4	0	40.0	3.9	91.7
1993	6	4	5	0	55.6	3.5	95.3
1993	7	2	3	1	60.0	2.4	97.6
1993	8	0	6	0	100.0	2.4	100.0

Table 7. Archery harvest data, seasonal, Madison County, 1990-1993. (muzzleloader and handgun tables have similar format)

YEAR	MALES	FEMALES	UNKNOWN	TOTAL	PERCENT FEMALE
1990	120	45	0	165	27.3
1991	140	111	0	251	44.2
1992	103	73	0	176	41.5
1993	144	108	2	254	42.9

Table 8. Archery harvest data, success by permit type, statewide, 1993. (muzzleloader and handgun tables have similar format)

YEAR	PERMIT* TYPE	NUMBER ISSUED	KILL	PERCENT SUCCESS	MALE	FEMALE	UNKNOWN
1993	RE	120280	17389	14.5	12315	5019	55
1993	RB	0	0	0.0	0	0	0
1993	RA	13248	4040	30.5	967	3061	12
1993	FE	12034	820	6.8	735	82	3
1993	FA	12034	966	8.0	257	704	5

*RE Regular, either sex
RB Regular, antlered
RA Regular, antlerless
FE Free, either sex
FA Free, antlerless

Table 9. Archery harvest data, hunter/harvest density, statewide, 1992-1993. (muzzleloader and handgun tables have similar format)

YEAR	HUNTER DENSITY		HARVEST DENSITY	
	TOTAL AREA	WOODS	TOTAL AREA	WOODS
1992	1.63	13.71	0.35	2.96
1993	1.72	14.48	0.42	3.52

Table 10. Model past trends, Region 8, 1985-1993.

	INDEX			MODEL					REAL	
YEAR	RECON[a]	LANG[b]	K/E[c]	V[d]	P[e]	TOTAL[f]	THM[g]	THF[h]	KILL[i]	%♀[j]
1985	39918	32795	34645	39511	13352	52863	0.186	0.100	5474	38.3
1986	47371	54329	46687	44638	16465	61103	0.214	0.098	6857	34.5
1987	58123	64738	54745	49685	19925	69610	0.245	0.102	8583	32.9
1988	67741	53726	51592	54526	23325	77851	0.197	0.110	3630	40.3
1989	78207	93935	67077	60581	26060	86641	0.246	0.091	10640	30.3
1990	93496	102065	56746	66169	27595	93764	0.253	0.110	12620	35.1
1991	116056	107310	61440	71696	28155	99851	0.295	0.168	15558	42.7
1992	120370	105652	52145	73016	28301	101317	0.329	0.170	16524	41.2
1993	123180	98930	51569	73135	28327	101462	0.246	0.175	16894	41.2

[a]Reconstruction population estimate
[b]Lang/wood population estimate
[c]Kill/unit effort population estimate
[d]Vulnerable segment of modeled population
[e]Protected segment of modeled population
[f]Total modeled population
[g]Total harvest of males (all weapons + crippling)
[h]Total harvest of females (all weapons + crippling)
[i]Actual harvest (all weapons)
[j]Percent females in actual harvest

Table 11. Model harvest simulation, 5 year period.

YEAR	POP	KILL	PERCENT FEMALES	PERCENT AD MALES	HARVEST RATE			RATE POP CHANGE
					MALES	FEMALES	TOTAL	
1	3293	875	41.5	15.3	0.35	0.20	0.27	0.027
2	3383	898	41.5	15.3	0.35	0.20	0.27	0.027
3	3476	923	41.6	15.2	0.35	0.20	0.27	0.024
4	3559	946	41.5	15.2	0.35	0.20	0.27	0.023
5	3643	967	41.6	15.3	0.35	0.20	0.27	0.022

Table 12. Model harvest simulation, results by permit type, 1 year period.

YEAR	PERMIT TYPE	NUMBER ISSUED	KILL	PERCENT SUCCESS	ANTLERED	ANTLERLESS
1	FULL ANTLERED	0	0	0.0	0	0
1	FULL ANTLERLESS	2250	783	34.8	0	783
1	FULL EITHER	4850	2156	44.5	834	1322
1	2ND ANTLERED	0	0	0.0	0	0
1	2ND ANTLERLESS	0	0	0.0	0	0
1	2ND EITHER	80	27	33.8	7	20

more - hit ENTER to continue

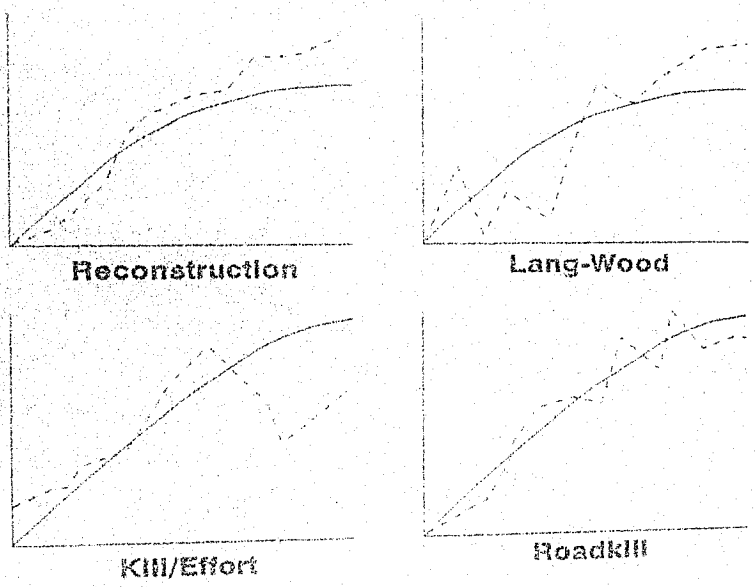

Figure 3. IDHAMP graphic output (solid line is model, dashed line is index).

APPENDIX B. IDHAMP data files.

File Name	Description
shotgun.bas -	shotgun harvest from 1957 by county, year, and sex/age class
shotgun.per -	shotgun harvest from 1980 by county, year, permit type, day of season, and sex/age class
archery.bas -	archery harvest from 1990 by county, year, and sex class
archery.per -	archery harvest from 1990 by county, year, permit type, biweekly period, and sex class
muzzle.bas -	muzzleloader harvest data from 1991 by county, year, and sex class
muzzle.per -	muzzleloader harvest data from 1991 by county, year, permit type, day of season, and sex class
handgun.bas -	handgun harvest data from 1991 by county, year, and sex class
handgun.per -	handgun harvest data from 1991 by county, year, permit type, day of season, and sex class
county.dat -	county, special area, region names and numbers for AREA LIST
area.dat -	square miles of total area and forest, male and female lifetime recovery rates, archery harvest as % of shotgun harvest, vulnerability coefficient for each county, special area, region, and state
roadkill.dat -	roadkills data from 1980 by county and year
idhamp.par -	FORTRAN include file containing model parameters

APPENDIX C. IDHAMP variables and file formats.

File Name	Format		
	Variable	Columns	Type
shotgun.bas	YEAR	2-3	I2
	AREA NUMBER	5-7	I3
	1ST DAY HUNTERS	9-13	I5
	GLOBAL PERMITS ISSUED*	14-18	I5
	GLOBAL PERMIT KILL	19-23	I5
	MALE 0.5	24-28	I5
	MALE 1.5	29-33	I5
	MALE 2.5	34-38	I5
	MALE 3.5	39-43	I5
	MALE 4.5+	44-48	I5
	FEMALE 0.5	49-53	I5
	FEMALE 1.5	54-58	I5
	FEMALE 2.5	59-63	I5
	FEMALE 3.5	64-68	I5
	FEMALE 4.5+	69-73	I5
shotgun.per	YEAR	2-3	I2
	AREA NUMBER	5-7	I3
	PERMIT TYPE	9	A1
	NUMBER ISSUED	11-14	I4
	1ST DAY MALE 0.5	15-18	I4
	1ST DAY MALE 1.5	19-22	I4
	1ST DAY MALE 2.5	23-26	I4
	.	.	.
	.	.	.
	.	.	.
	7TH DAY FEMALE 3.5	287-290	I4
	7TH DAY FEMALE 4.5+	291-294	I4
archery.bas	YEAR		I2
	AREA NUMBER		I3

APPENDIX C. Continued.

File Name	Format		
	Variable	Columns	Type
	FEMALE KILL		I3
	BOW HUNTERS		I4
	MALE KILL		I3
	FEMALE KILL		I3
	UNKNOWN SEX KILL		I3
archery.per	YEAR	2-3	I2
	AREA NUMBER	5-7	I3
	PERMIT TYPE	9	A1
	NUMBER ISSUED	11-14	I4
	WEEK 1-2 MALES	15-18	I4
	WEEK 1-2 FEMALES	19-22	I4
	WEEK 1-2 UNKNOWNS	23-26	I4
	WEEK 3-4 MALES	27-30	I4
	.	.	.
	.	.	.
	WEEK 15-16 UNKNOWNS	107-110	I4
muzzle.bas	YEAR		I2
	AREA NUMBER		I3
	MUZZLELOADER HUNTERS		I4
	MALE KILL		I3
	FEMALE KILL		I3
	UNKNOWN SEX KILL		I3
muzzle.per	YEAR	1-2	I2
	AREA NUMBER	4-6	I3
	PERMIT TYPE	8	A1
	NUMBER ISSUED	10-13	I4

APPENDIX C. Continued

File Name	Variable	Format: Columns	Format: Type
	1ST DAY MALES	14-17	I4
	1ST DAY FEMALES	18-21	I4
	1ST DAY UNKNOWNS	22-25	I4
	2ND DAY MALES	26-29	I4
	2ND DAY FEMALES	30-33	I4
	2ND DAY UNKNOWNS	34-37	I4
	3RD DAY MALES	38-41	I4
	3RD DAY FEMALES	42-45	I4
	3RD DAY UNKNOWNS	46-49	I4
handgun.bas	YEAR		I2
	AREA NUMBER		I3
	HANDGUN HUNTERS		I4
	MALE KILL		I3
	FEMALE KILL		I3
	UNKNOWN SEX KILL		I3
handgun.per	YEAR	1-2	I2
	AREA NUMBER	4-6	I3
	PERMIT TYPE	8	A1
	NUMBER ISSUED	10-13	I4
	1ST DAY MALES	14-17	I4
	1ST DAY FEMALES	18-21	I4
	1ST DAY UNKNOWNS	22-25	I4
	2ND DAY MALES	26-29	I4
	2ND DAY FEMALES	30-33	I4
	2ND DAY UNKNOWNS	34-37	I4
	3RD DAY MALES	38-41	I4
	3RD DAY FEMALES	42-45	I4
	3RD DAY UNKNOWNS	46-49	I4

APPENDIX C. Continued.

File Name	Format		
	Variable	Columns	Type
area.dat	AREA NAME	1-11	A11
	AREA NUMBER	13-15	I3
	TOTAL SQUARE MILES	17-21	F5.0
	FEMALE LIFETIME RECOVERY RATE	33-36	F4.2
	ARCHERY HARVEST AS % OF SHOTGUN	38-41	F4.2
	C COEFFICIENT	43-50	F8.7
roadkill.dat	YEAR	[b]	I2
	AREA NUMBER		I3
	NUMBER OF ROADKILLS		I5

[a] Full season, any-deer permits.

[b] Free format (variables separated by blanks)

APPENDIX D. Parameters in IDHAMP include file.

Proportion of winter mortality occurring before January 1

Proportion of initial population (in user-defined area) in various sex/age cohorts

Number of weekends in hunting season

Temporary increase in C to simulate opening day vulnerability

Proportion of "no shows" on last day of 1st season

Proportion of 2nd season "no shows"

Shotgun crippling rate for antlered and antlerless deer

Archery crippling rate for antlered and antlerless deer

Regression coefficients for winter mortality-density curves for each of 6 sex/age groups of the type:

$$Y = a + bX^{p}$$

(a = base level set from parameter menu)

Regression equations for similar summer mortality-density curves

Slope of reproduction-density regression lines

Percent of males among offspring produced by fawns, yearlings, and adults

Proportion of biological carrying capacity where reproduction begins to decline for fawns and yearling/adult females

Maximum dispersal rate for fawns

Regression coefficients for male and female fawn dispersal curves

Dispersal rate for yearling females

Appendix D. Continued

Survival rates for dispersing fawns and yearlings

Last year of shotgun, archery, muzzleloader, and handgun harvest data

---